Chair's Summary of West Coast Protected Fish Species Science Program Review
Northwest Fisheries Science Center and Southwest Fisheries Science Center
May 4-8, 2015

Review Panel Members

- Daniel Schindler, University of Washington, Chair
- Ken Currens, Northwest Indian Fisheries Commission, Reviewer
- David Hankin, Humboldt State University, Reviewer
- John Kocik, NOAA-F, Northeast Fisheries Science Center, Reviewer
- Anke Mueller-Solger, USGS, California Water Sciences Center, Reviewer
- Jennifer Ruesink, University of Washington, Reviewer

Background and Overview of Meeting

The review panel met at the Alaska Fisheries Science Center in Seattle from May 4-8, 2015, to review the science pursued by NOAA relevant to protected fish species on the US west coast. The panel considered the following overarching questions, as described in the terms of reference, in evaluating the information provided to us during the review and in crafting our final report:

1. Do current and planned protected species scientific activities fulfill mandates and requirements under the ESA and MMPA, and meet the needs of the regulatory partners?
2. Are there opportunities to be pursued in conducting protected species science, including shared and collaborative approaches with partners?
3. Are the protected species scientific objectives adequate, and is the best suite of techniques and approaches to meet those objectives?
4. Are the protected species studies being conducted properly (survey design, statistical rigor, standardization, integrity, peer review, transparency, confidentiality, etc.)?
5. How are advances in protected species science and methodological approaches being communicated and applied in NMFS?

(from Terms of Reference (TOR) for NOAA Fisheries Science Program Reviews, 2015 Protected Species Science)

The first section of this document is the Chair's Report, which summarizes the key points raised by the panel during the review. This summary is not a consensus of opinion from all panel members so it deviates from some comments made by individual reviewers as provided in the subsequent sections. The basic format of this review reflects the agenda themes used to organize the workshop. We have also included some additional comments about the format of the review, and have moved our comments about invasive species out of the hatchery section and into a new theme at the end of the report.

General Observations and Recommendations

General Considerations

- The panel was impressed with the broad diversity of science pursued by NOAA to address scientific needs for managing protected species on the US west coast. NOAA scientists are clearly talented and motivated, and are contributing cutting-edge science with many clear benefits to management of protected species and to the broader scientific literature on related topics.
- The scientific growth over the last 25 year within NOAA relevant to protected species management has been spectacular. Development of the ESU concept and how it can be applied to prioritizing science and management of protected species is one example of the scientific contributions from NOAA.
- In general, NOAA has been extremely effective at applying complicated science in management.
- As best we can tell, NOAA scientists appear to be meeting the mandates of ESA and satisfying the primary needs of managers and decision-makers; however, we were not presented adequate information on some themes to fully address this question during the review.
- NOAA has also been remarkably successful at developing meaningful collaborations with scientists in academia and in other federal and state agencies. These relationships serve the agency well in times of tightening budgets, but also are critically important for developing the best science relevant to managing protected species.
- The panel also noted several research activities that would benefit from increased efficiencies and improved integration. In particular, because the science relevant to protected species is so diverse, it is a major challenge to integrate across the various disciplines involved. However, we believe that more effort and incentives should be placed on integration among the science themes described to us (e.g., connecting life-cycle modeling to toxicology).
- The complete lack of discussion of coordination between the natural sciences and economics and other social sciences was noteworthy. The panel realizes that there is a separate review planned for social sciences research; however, that the natural sciences and the social sciences were reviewed independently is likely symptomatic of weak coordination between these disciplines. Given the immense complexity involved in recovery planning for protected species, the panel stresses that more effort should be placed on integrating the relevant social and natural sciences that bear on recovery efforts.
- It was unclear how the two science centers coordinated their research activities. We were provided a small number of examples where staff from one center would participate in the field program of another but coordination at the planning, synthesis, and implementation stages was not readily apparent. We encourage more scientific coordination between the NWFSC and SWFSC as they have much to learn from each

other and better coordination will likely improve the impact of the science on management.

- While the term adaptive management was used to describe various aspects of the science, it was not clear how links and feedbacks between science and management were operationalized. It is possible that there is more integration and feedback between science and management than we were presented during the workshop; however, without hearing directly from managers and decision-makers who are working on the ground, it was difficult to assess whether the science-management interaction was a strength or a weakness of the protected species science.
- Related to the latter point, it was also unclear how NOAA evaluated regulatory effectiveness, particularly in the habitat restoration and protection work.
- The panel also highlights that the lack of funding for making new permanent hires is a serious risk to the long-term institutional memory of protected species science in the agency. How will NOAA maintain their institutional memory of protected species science on the west coast? This is going to require tough politicking and making difficult decisions about which scientific programs to continue investing in. Some strategic planning focused on strategies for replacing senior scientists over the next decade should be done very soon.

Below we provide more specific responses to the various scientific themes presented during the panel review. In each theme we describe our observations on the strengths and challenges of each research theme, and provide recommendations in response to these observations. The comments provided in this Chair's Summary describe what the panel felt were the main issues to consider. More detailed comments are provided in each of the individual reviewer reports.

Panel Members' Major Recurrent Observations and Recommendations

Theme 1 – Recovery Science Overview

- The review process would have benefitted greatly from a more focused introduction to the key issues facing science and management by NOAA on protected species. In particular, the scientific program could have been better framed within a decision-making framework.
- It would have been helpful to the review panel (and helpful to NOAA Fisheries in the long-term) to develop a process that will be used to prioritize science activities moving forward; a structured decision-making framework would help immensely.

Theme 2 – Monitoring and Sources of Data

- The biggest challenges to developing and maintaining a credible and informative monitoring program are organizational not scientific. NOAA has generally done a very good job with a difficult problem in its attempts to coordinate with a variety of partners collecting data on protected species and their habitats on the west coast. However, it was

not clear how data quality is assessed, particularly those collected by partners. This needs to be made a higher priority.

- While there is pressure to standardize methods across projects and systems, there are often good reasons to maintain project- and system-specific methods. (e.g., redd counts do not work everywhere).
- NOAA scientists have been very effective at implementing emerging technologies (e.g., fish tagging methods) in their monitoring projects.
- We encourage the monitoring programs to become better integrated with the life-cycle modeling efforts. Modeling can be used to assess the monitoring, and vice versa, more so than it currently is.

Theme 3 – Habitat Science

- The habitat science is very strong and has produced an impressive body of knowledge regarding habitat protection and restoration. The science is clearly question-driven and attempts to operate within an adaptive framework (i.e., learn from experience).
- The habitat science would benefit from more explicit integration with both life-cycle modeling and with economics. The former would be useful for better understanding biological responses to restoration. The latter would be useful for developing more formal assessments of the costs, benefits, and risks of individual habitat projects.
- The Elwha River restoration is a remarkable opportunity to learn about river restoration. The panel was somewhat surprised that NOAA has not made a more concerted effort to champion this project. The panel was impressed with the quality of the results that were summarized from the first years of the restoration. Some of the most interesting results may take decades or longer to play out and we strongly urge NOAA to assess whether they have invested enough resources to fully monitor the ecological responses to restoration. Long-term commitment to this project should be made a highest priority to ensure that the maximum knowledge is derived from this experiment. The Elwha restoration is also a remarkable public relations opportunity at both regional and national scales. In general, the panel felt that the Elwha research program was not given the status and funding that it probably deserves given the unique opportunity it presents.
- The contaminant science was interesting and clearly at the cutting edge of this discipline. However, the panel believes there could be more attention focused on integrating this work with the other recovery sciences. Again, life-cycle modeling provides the framework for this, assuming it is developed appropriately.
- We encourage the NOAA contaminant program to develop a national strategy describing its research goals in this area. It is also critically important to coordinate this effort with other federal agencies (i.e., EPA) to maximize its success.

Theme 4 – Climate Change

- A key strength of the science focused on climate change is in developing decision-support tools to explore the implications of changing climate on protected species and

their habitat. In general the panel felt this research area would benefit greatly from more investment by NOAA.

- Climate science is an obvious need for assessing and adapting recovery plans. Most work has been provided by outside partners, particularly from within academia. NOAA would benefit from more of its own work here.
- Better integration with life-cycle modeling will improve the value of the climate science. However, much of the current life-cycle modeling is somewhat ad hoc and could be vastly improved by using more formal methods for synthesizing data describing life-history and demographic responses to changing climate. Current efforts to do so seem overly optimistic about our understanding of many environment-demographic relationships – particularly in freshwater habitats, despite enormous amounts of data.
- We encourage NOAA science and policy teams to explore whether recovery criteria can be revised based on climate projections.

Theme 5 – Survival in Rivers

- Much of the work studying survival in rivers is well-founded, question-driven science. In the California Central Valley, the research is particularly strong. In the Columbia River the research seems somewhat ad hoc (though we realize it is a much larger and more complex ecosystem). Work in the Columbia River would benefit from more coordination among the various groups within and outside NOAA who are executing the science to quantify survival in the river. Again, more explicit effort within the life-cycle modeling would likely help achieve this.

Theme 6 – Estuary and Ocean

- Though the marine habitats used by protected species are vast and complex, and extremely difficult to study, the panel felt that the marine science work presented had several weaknesses. First, the justification of the work relevant to the management of protected species was not clearly articulated for the work in the Northern California Current (NCC). It is widely appreciated that little is known about salmon ecology in the ocean; however, we saw little effort for self-assessment to evaluate what was being learned through various projects. In several instances, the marine science also suffered from lack of central questions or hypotheses, and weak mechanistic underpinnings (primarily in the NCC work). This research is extremely expensive and should therefore be justified and evaluated with the most scrutiny.
- Research in estuaries had more merit than much of the coastal work, though there is a distinct need to study the responses to restoration over ecologically-relevant time scales. Short duration studies of fish distributions and trophic ecology are not a replacement for understanding how habitat restoration translates into demographic performance (i.e., metrics relevant to protection).
- We encourage any further work on growth performance or physiological indicators to use more appropriate metrics for assessing links to demographic responses. For example, for several reasons, annual Bonneville dam counts are not a good metric of marine survival.

Indicators such as SAR or, better yet, estimates of mortality from release to ocean age 2 (based on coded wire tag recoveries) or stage-specific mortalities (based on acoustic tags or PIT tags) should instead be used. We appreciate that there are distinct time lags involved in obtaining the data needed to estimate these more direct measures of demographic performance; however, the current links between the physiological work and the demographics of protected species were somewhat weak.

- Given the large cutbacks on marine research, it is important to ask what can be learned from different levels of sampling effort in the coastal ocean. It is clear that the Newport line is valuable for understanding certain aspects of the dynamics of the California Current ecosystem. However, the real value of the broader spatial surveys in the NCC that can only be undertaken once or twice a year, needs to be more honestly evaluated. This research seemed remarkably ad hoc and weakly executed. We suggest a thorough internal review of the Estuary and Ocean sciences theme, to assess what is being learned and at what cost. The work presented for Southern California Current juvenile salmon movement through the nearshore marine habitat was compelling and should serve as a model for how the work farther up the coast could be improved.
- Coordination with stock assessments on commercial species has the potential to greatly benefit the marine research.
- The stop-light approach for understanding coastal ocean dynamics is of questionable utility. We agree that it has potential to improve communication of complex data sets to non-scientific audiences. However, is it communicating the right information? Further, if this effort is intended, in part, to provide a leading indicator of salmon returns or survival, why is it not being compared to more rigorous statistical approaches that have shown some success in the past (e.g. coastal upwelling intensity as a leading indicator of SARs)? This is another example where some serious self-evaluation of whether the research is having its intended impact is needed.

Theme 7 – Harvest

- NOAA has generally done a very good job at assessing harvest on protected salmon stocks
- It is unclear whether NOAA routinely assesses whether exploitation rates on protected stocks are appropriate for enabling recovery. Such assessments should use state-of-the-art statistical approaches for estimating and understanding uncertainties (observation and process errors) in estimates of stock-specific harvest rates.
- The management strategy evaluation on Sacramento Chinook stocks was an excellent example of using most of the data in hand to assess different alternatives for achieving appropriate protection for at-risk stocks.
- The parental-based tagging approaches seem to hold a lot of potential. However, their utility in different systems needs to be more thoroughly explored.
- The project using commercial fishers to collect DNA samples from Chinook salmon in the ocean was a noteworthy example of outreach and collaboration with non-scientists. The scientific opportunities from this work are intriguing but need to be more formally

assessed for possible sampling biases. More focused work needs to be done to ask how this type of data could be used in scientific assessments.

Theme 8 – Hatcheries

- The panel was impressed with the high level of integration across the hatchery science work.
- One potential weakness was the focus on the genetic and life-history dimensions of hatchery effects with very little focus on understanding potential ecological effects on wild fish.
- Some concern was raised about how NOAA was involved in planning, implementing, and assessing re-introductions.

Theme 9 – Evolution and Life History

- The research on evolution and life history variation in protected salmon is world-class. One key example here is the development of the ESU concept, and its implementation as the framework within which to develop recovery efforts.
- It was somewhat unclear how some of the research in this theme has direct management relevance. It is clear that much of the research is contributing to basic knowledge on protected species. However, some self-assessment of management relevance of the research in this theme would certainly be worthwhile. Again, this would take a long-term evaluation but the importance of quantifying outcomes is warranted.
- Research on epigenetics is at the cutting edge of applied genetics. More clearly articulating the direct application to management of protected species will be important for protecting this work in the future. This research seemed to hold substantial promise for making important breakthroughs in protected species science.

Theme 10 – Life-cycle Modeling and Synthesis

- Life-cycle modeling is critical for achieving the goal of an integrated science program to provide the information needed to manage protected species. Essentially all aspects of the science presented at the review would benefit from integration within a formal life-cycle framework that includes numerical models and improved methods for synthesizing existing data. Life-cycle modeling and the associated statistical research should be a high priority of achieving synthesis across the many dimensions of protected species science at NOAA.
- The work presented has substantial room for improvement. The modeling efforts seemed somewhat ad hoc, particularly in the Columbia River work, and would benefit from more formal approaches that can synthesize and integrate across the data limitations that are impossible to avoid in protected species management.
- It was not clear why there was not more integration between other quantitative scientists at NOAA and the groups developing the life-cycle models. Several new approaches to synthesizing large, messy data sets have been developed by other quantitative scientists

within NOAA, that explicitly enable estimates of process and observation errors. We saw some application of these approaches in the work on Puget Sound rockfish and in eulachon. However, such formal integration and synthesis was not apparent in the salmon research. Given the complexity of the ecosystems being studied, and the many limitations of data collected to parameterize life-cycle models, the panel strongly recommends that more attention be paid to more formal syntheses of existing data that account for observation and process errors and, therefore, more realistic statistical descriptions of demographic responses to environmental variation.

Theme 11 – Non-salmon Species: Green Sturgeon, Eulachon, and Rockfish

- Overall the panel was impressed with the science that was accomplished on these species with little funding and small staff commitments.
- The research on green sturgeon seems to have the greatest need for more funding to support basic management-relevant research. The small population size and uncertain recruitment dynamics of green sturgeon justify high priority for further research on this species.

Theme 12 – Non-native Species

- Synthesis efforts on non-native species and how they might interact with protected species was eye-opening and valuable. How this work could be connected to the other research themes (in particular the river survival and the habitat science) needs to be better described.
- While improving public awareness of the threats to salmon by non-native species is clearly needed, we were not convinced that this should be a central activity for NOAA. There are many other potential partners doing this type of work who could be better coordinated with NOAA science programs.

Overall comments on the review process

- The panel struggled at times with answering the questions regarding whether the science being produced by NOAA was meeting the needs of managers and decision-makers. It would have been helpful to hear the perspectives of the science users to evaluate these issues. Thus, without a more explicit context provided by managers, including from tribes and other users, we can make only vague statements about how useful the science has been.
- The science would have been easier to evaluate if there had been more presentations by the specific individuals who actually perform the science.
- Each talk would have benefited from an opening slide that explicitly stated the management needs/questions/objectives of each theme. Some presentations were good in this regard; we had to guess in many others.

Reviewer #1 Report: Protected Species Panel, May 7 2015

Background Statement

Overall, I was greatly impressed by the caliber of research that was presented during the many talks and, in many cases, by the very clear and direct ties to important ESA-related management applications. The sessions have reinforced my belief that the NMFS Science Centers carry out first rate research and, in my mind, are models for the quality of science than can be achieved within federal agencies. In my more specific comments below, I address the specific research themes that were identified during the presentations. I caution that some of my reactions to presentations may be off target because I have misinterpreted the content of the presentations and I have not had time or opportunity to review the overwhelming number of journal publications that were referenced in the presentations. (NMFS folks are to be complimented on getting their fine work in the peer-reviewed literature.)

Before getting to my review of the various thematic areas of research considered during the workshop, I would like to note that there is some room for improvement in the future structure of these reviews that would simplify panel function and probably generate a more useful future review product. First, it would be helpful if all presentations could be available on a USB at the time of the review sessions so that panel members could efficiently review presentations, if needed, without having to access them online through what proved to be sometimes problematic internet connections from hotel rooms! Second, although the hard copies of presentations were useful for note-taking during presentations, they were almost unreadable due to the small size and poor quality of slide reproductions. Third, additional clarity in the panel charge and how the recipients would most like to receive panel comments would have been appreciated prior to the workshop itself. Fourth, it would have been very helpful if a simple organization chart, with names and titled indicated, had been circulated right at the beginning of the session so that the within agency status and roles of individuals were more clearly identified to panel participants. I managed to figure this all out by the end of the session, and realized that all participants had in fact identified themselves before their presentations, but this has to be in a very obvious and perhaps more overt fashion to penetrate the mind of at least one panel members who is not himself an agency scientist. Finally, a tighter focus in the introductory talks summarizing the essential "main issues of concern" wrt ESA-listed species (or ESUs), right at the beginning of the sessions, would have helped frame the proceedings and helped reviewers to determine whether or not research projects were on target wrt addressing these main issues of concern. Such introductory talks would have been especially useful for panel members who have not been actively involved in salmon research and management. Addressing all or some of these identified issues would probably make for a more effective review process during the next "round". Even without these changes, however, I found the workshop process to be very interesting for me personally and I hope that my comments below are of some value.

Comments on Specific Themes

Theme 1: Overarching Issues and Needs

As noted above, at least this Panel Reviewer got a bit lost in the list of "example needs" that were presented in the presentation concerning "West Coast Region science needs and legal mandates". My hunch is that there was too much emphasis placed on generic legal requirements (which apply to all listed species) and on the number of required consultations for ESA-listed salmon (which appears to be primarily a Region responsibility that often does not require assistance from the Science Centers), and not enough on the very specific research needs and legal mandates that are unique to salmon and to the other listed species considered during the review. Looking back over the slides that were used in this presentation, I suspect that delivery rather than content contributed to my not developing a firm grasp of the specific issues that were judged of greatest importance. Many of these appear to have been pretty clearly listed on the slides.

Strength:

- The Centers have very clearly established effective collaborative arrangements with contractors and have, together with these contractors, generated top-rate science, BUT

Concern:

- The extent to which both Science Centers rely on term hires and contractors seems excessive and potentially not cost-effective. The learning curve required for new scientists to become actively involved in existing long-term projects (e.g., CV life cycle modeling) must be steep and time-consuming and may account for a relatively large fraction of the total time that a term employee or contractor may work for the Centers.
- The issue of cross-center coordination of salmon research should receive greater and more explicit attention in further reviews. There is plenty of salmon research to do, but it was unclear just how the NW and SW Centers work together (or do not) on this research.

Theme 2: Monitoring and Sources of Data

I have no particular comments on this Theme. Having served on the Central California Coastal TRT, I am well aware of the near absence of historical monitoring data in that part of California and it very obviously limits the sophistication of ESA-related analyses that can be generated. Other regions are much farther ahead, as noted in a Theme 2 presentation. Monitoring is primarily a state responsibility, although the Science Centers can assist states in developing survey designs, monitoring protocols, etc. I do have one concern that is perhaps worth relaying, however:

Concerns:

- Standardization of monitoring protocols should be recommended only when a monitoring protocol can consistently generate reliable and (hopefully) unbiased estimates or indicators of target attributes. When survey protocols, such as red counts in California streams, cannot meet this test, there should be room for survey protocols to vary by location. At each survey location, the objective should be to deliver reliable and unbiased estimates of well-identified and well justified target attributes, regardless of survey protocol. It's much better to have variation in survey protocols that deliver useful information than it is to insist on standardized application of survey protocols that fail in certain areas due to differences in rainfall patterns or other factors.

Theme 3: Freshwater Habitat Research and Restoration (and Toxicology?)

The two presentations on habitat were very nicely delivered and interesting.

Strengths:

- Studies documenting the response of sediments, river channel, and anadromoussalmonids to dam removal on the Elwha River are fascinating and should receive the very highest level of support given the proposals for similar (and more extensive) dam removal projects elsewhere. The objection that this is "n=1 science" is an absurd one as this argument can be made validly for almost all field research in natural resources. There is only one Elwha River, there is only one Columbia River, there is only one Sacramento River, and so on. The classic notion of "replication", e.g. inoculating identical numbers of microbes in replicate test tubes as I did during my college microbiology class (which I loved), is essentially impossible in most natural resource science settings.
- There have been a very large number of restoration projects implemented throughout the Northwest and NMFS seems to know the location of every one of them!
- Perhaps due in part to the TRT processes, it appears that there have been substantial advances in understanding how physical attributes of habitat translate into capacity for supporting anadromoussalmonids, BUT

Concerns:

- Follow up evaluation of restoration projects has been generally poor. For example, in CA agencies are willing to support restoration projects using pass through federal funds, but not subsequent monitoring of project effectiveness in terms of habitat or support of fish (a problem that cannot be blamed on the Science Centers!)
- Many of the conjectured benefits of habitat restoration seemed conditioned on the presumed effectiveness of the restoration activity (in terms of achieving desired physical habitat changes) and assumed increased habitat utilization by fish). The benefits of

habitat restoration activities may be oversold (see later comments on life cycle modeling) or at the very least are inadequately characterized. I was very surprised to see no cost/risk/benefit analyses of this topic and suggest that an economist should be encouraged to collaborate with the habitat restoration group if that has not already been taking place.

I confess that I did not know what to make of the Toxicology presentation and could not judge whether or not the NW Center should continue to support a large continuing effort in this area. For example, the issue of non-point source pollution is hardly a new one, affects all aquatic life (not just fish), and is hardly an unrecognized issue by federal and state regulatory agencies. However, if it is indeed true that methods used by EPA to assess effects of toxic compounds on fishes are inappropriate or inadequate or non-existent, then it certainly seems that continued NMFS involvement in this area is essential to at least "train" EPA in how better to approach these issues. Therefore, I make the following recommendation (per one of the bullets on the final slide in the Toxicology talk):

- Develop a national-level strategy or NMFS science specific to how best to address toxic effects of ocean pollution and non-point source runoff on listed species and their habitat. *EPA participants should be involved in this process.*

Theme 4: Climate Change and Salmon Recovery

There is absolutely no question that the Science Centers need to maintain and enhance their science efforts on effects of climate change generally and on the implications of climate change on strategies for recovery of listed species. Mantua's overview talk was interesting, although it was surprising to me that so little of this talk concerned possible changes in ocean climate. Projected changes in climate (Eastern OR /WA/ Columbia River = Central Valley thermal regimes by 2040), if true, brought home to me that climate change may be moving ahead more rapidly that I had imagined.

Recommendations:

- IF this is possible, previously specified recovery criteria should be reexamined and reconsidered in light of future climate change scenarios. For example, current recovery criteria may say that "3 of 6 independent populations" need to be viable before the ESU can be delisted, but climate change models may suggest that 3 of these populations will face unsuitable thermal habitat in the near future. That would mean that all recovery effort should be directed to the three populations that may have a chance to survive. Clearly, this issue should have strong influence on recovery planning.
- NMFS Science Centers should probably take a more active role in providing assistance in recovery planning, given climate change scenarios. (I'm not sure this issue was even discussed in our sessions?) "Stakeholders" often wish to adopt recovery measures at all

locations, but climate change scenarios pretty clearly point to the value of a triage system (see above bullet).

- Given the fact that very tough and politically unpopular decisions may need to be made regarding recovery strategies (e.g., "yes" to my favorite stream but "no" to your favorite stream (doomed to be uninhabitable in the near future), I think it would be valuable to enlist the assistance of social scientists to help develop strategies for helping stakeholders to "work through" these kinds of issues. I was struck that there was neither social science nor economics considered at any point during the workshops: that is odd, I think.

I really struggled with the case study examples of how climate change might affect recovery of Snake River Chinook. Although there's no doubt in my mind that this is exactly the "kind" of work that should be done (ie., it is addressing the correct issues), I cannot comment on whether or not the work is being carried out in the best possible fashion. The conclusion that ocean survival has a greater effect on extinction risk than freshwater survival hardly seems surprising to me given the typical relative magnitudes of survival in the two environments. Based on CWTs (no fancy modeling here), annual survival rates (release to ocean age 2) of Klamath River hatchery yearling Chinook have ranged from 0.00185 to 0.24931 over the past 25 years or so. Typical survival rates from egg deposition to smolt are typically in the 3% ballpark, I think, and do not show this level of extreme variability.

Theme 5: Survival in Rivers

The presentation on Science Center involvement in Columbia River tagging designed to allow estimation of survival rates via repeated re-sighting of PIT-tagged individuals was a real eye-opener for me. I had assumed, incorrectly I guess, that USFWS and the states of OR and WA had taken the lead in this area (see Burnham et al 1987). I was also very, very interested to learn that the survival rates from the upper Snake to Bonneville Dam are so very high (something like 0.4-0.7) compared to what I had anticipated (much lower!).

Strengths:

- The apparent long-term involvement in Columbia River survival studies, the self-evident (to me) importance of these studies, and the now well-developed statistical methodologies to analyze re-sighting recoveries of PIT tags at Columbia River dams, together make for a strong program in this area and one that should be maintained (at a level that I cannot judge).

Concerns:

- For an anadromous species that returns at multiple ages, survival from release to ocean age 2 is a much better measure of ocean survival than SAR. SAR across populations is confounded by stock-specific differences in age-specific maturation probabilities and ocean exploitation rates. Can CWT cohort reconstruction methods (and perhaps paired

CWT and PIT-tagged releases) somehow be used to improve upon SARs as a measure of survival?

- There are TONS of tagging efforts on the Columbia River and it was unclear to me, even after questions, whether or not there was adequate coordination among very expensive tagging programs. (I believe that BPA recently commissioned a report dealing with tagging within the Columbia River, although I have not taken a look at it.)
- Estimation of effects of predators below Bonneville Dam on downstream survival of smolts and upstream survival of adults should have exceptionally high priority. The *issue* was discussed repeatedly, but I do not recall much discussion of approaches to estimating survival impact or controlling predators. (I could be wrong here!)

I thought that the presentation that Sean Hayes gave on his various SW Center projects concerning survival of CV Chinook through the nasty Sacramento River environments was perhaps the best talk given at the sessions. He began with a wonderful if brief overview of CV system plumbing and its problems, his research seemed always to have an exceptionally clear connection to clearly important management issues, and he had some interesting recommendations to make. He won my award for "best presentation".

Strengths:

- Research addresses very clearly identified management problems (downstream migrant survival through main stem Sacramento; downstream migrant survival through San Joaquin) and the apparent important role of predators in depressing survival rates.
- Objectives of Delta Predation Studies are clearly pertinent. It is amazing that such studies have not been done previously.
- Methods used in studies seemed highly imaginative and effective to me (e.g., use of tethered fish and go pros!).
- Research seemed to produce some very practical and important management recommendations: (a) use of pulse flows to coordinate with hatchery releases or peak migrations of wild fish – to get fish through system as fast as possible; and (b) identification of predation "hotspots" throughout system and concentrating predator control measures at those locations.

Theme 6: Estuary and Ocean Science

First, I should state that I am predisposed to favor studies of the effects of oceanographic variables on survival of Chinook salmon. I recently directed an MS student who did a very thorough (and very unsatisfying) examination of how oceanographic factors may influence survival of Klamath River Chinook, and I have messed with CWTs for estimation of survival rates for the past 30 years. Having stated that, however, I have to say that the presentations given on ocean survival studies generated a very "mixed" response from me as compared to the other themes presented during the review process:

Strengths:

- Evidence of stock-specific spatial patterns in use of nearshore (?) ocean habitat following ocean entrance is very neat and theoretically is exactly the kind of information that is needed to support thoughtful assessments of the impacts of oceanographic variables on survival of juvenile salmon during their first year in the ocean.
- Hayes work concerning selective mortality is quite interesting and seems very consistent with empirical data generated from Klamath CWT releases that I will be sending along to him.
- Hayes work in Scott Creek estuary was also very interesting and presumably relevant for many other small streams in CA and OR coast that form lagoons during the summer months.
- Salmon River estuary work has been a "poster child" of possible life history diversity benefits that can be achieved in small watersheds where substantial habitat modification is quite feasible.
- I agree that third generation ocean forecasting models should be more along the lines of the new MARSS models and that they should explicitly attempt to match up oceanographic variables in time and space with the apparent movements of juveniles that have been identified (see bullet 2 below).

Concerns:

- I remain concerned by the widespread use of Spring Chinook counts at Bonneville as an indicator of ocean survival. Among other things, no data were presented demonstrating the stability of hatchery releases or of the correlation in survival rates across hatchery spring Chinook stocks, and fish returning from a cohort are obviously (and variably) represented in multiple years as adults. My objection to the use of this kind of "proxy value" for survival rate is similar to that lodged against use of SARs. We can (and should) do better.
- It seems to me that we should by now be well beyond the kind of qualitative relationships presented in this session. First, I don't see how qualitative "grouping" of continuous variables (indicators) can lead to useful predictive forecasts. Use of qualitative "stoplight" graphics is a wonderful device to communicate notions of "poor" or "favorable" ocean environments to members of the public, but I don't see this as a framework for useful quantitative statistical modeling designed to produce environment-driven forecasts. Second, I could not tell if the "forecasting" models were actually intended to have practical applications or were merely intended to generate insights. Third, and most important, I saw no evidence of the kind of mechanistic thinking that should normally accompany specification of proposed models and model selection and neither did I see any attempt to treat oceanographic variables in a fashion that corresponded to the temporal and spatial movements of juveniles that were considered during the same set of presentations.

Theme 7: Harvest Science

I've actively participated worked in this area for decades and I believe that NMFS Science Center involvement in development of models used to manage Pacific salmon within the PFMC and PSC contexts (Mohr, Kope, O'Farrell, Lawson) has been absolutely essential. Without assistance from the Science Centers, modern assessment models would probably still be almost entirely Excel spreadsheet models.

Strengths:

- O'Farrell's description of the winter run management strategy evaluation seems an excellent example of Center scientists addressing an important listed species issue in a fashion that is of direct relevance to fishery management.
- Lawson's presentation on collaborative research involving commercial salmon fishermen has developed some extremely interesting new findings on ocean distribution of Chinook salmon and should be encouraged if only because it provides a wonderful illustration of a collaborative project with industry that has generated fascinating new observations that would not otherwise have been generated.

Concerns:

- The number of FTE that appear to be allocated toward direct participation in the PFMC process as it pertains to listed species (or all together!) seems marginal to me and the issue of future transition (for Kope) was raised.
- Although I personally find the results from Lawson's collaborative project to be fascinating, it is by no means self-evident that project results can have direct fishery benefits within the existing management framework. That is, it is unclear just how project findings might be used to improve upon existing management. In the final years of the project, I believe that project thrust should be shifted to that topic rather than just continued collection of data.
- I remain very concerned that ocean exploitation rates for CV fall Chinook salmon remain too high for relatively unproductive natural populations to withstand without eventual extinction. Is NMFS unable to become actively involved in this issue just because fall Chinook in the CV are not a "listed population"? Or can NMFS exercise some influence under more generic MSFCMA authority that calls for "sustainable fisheries"?

Theme 8: Hatchery Science

Over the past two decades, there has been an enormous surge of interest and activity concerning possible negative impacts of hatchery propagation on status of natural populations, and possible ways that hatcheries could instead play positive roles in recovery of listed populations. Presentations in this session provided good examples of the kinds of activities that are taking place in this area.

Strengths:

- The NW and SW Centers have outstanding scientists (e.g., Berezikian, Garza/Anderson) who have developed cutting edge methods (e.g., parental-based tagging) and understanding of many issues relating to operation of hatcheries.
- Problems identified as worthy of attention by this group all seem worthy or attention.

Concerns:

- Non-native species research did not seem to be a good "fit" relative to "hatchery science". It seems to me that study of non-natives in the context of listed ESUs of salmon and steelhead should be limited to study of species (like pikeminnow, striped bass) which very clearly are important predators of juvenile salmon. But the scope of the presentation went well beyond such nonnative species and instead considered ballast water impacts, green crab advance, invasive eelgrass. IF the invasive species group is intended to directly support listed salmon and steelhead, then a narrowed focus seems more appropriate. (This comment is NOT intended to imply that study of invasive species is not of interest or importance, just that it did not fit will within the agenda presented at the sessions.)

Theme 9: Evolution and Life History Overview

The work of Waples, Ford and Hard at the NW Center, and also Garza, Anderson and Pearse at the SW Center, has been absolutely outstanding and there is no question in my mind that the strength of these groups should be strongly supported in the future. Much of the work done in these groups has been "ahead of the times" and, to me at least, closer to "basic science" than any other research presented during the sessions. Given the absolutely remarkable increase in the application of genetic methods in the field of fisheries over the past two decades, it is hard to argue that continued support of this kind of research in unlikely to generate important insights as well as practical applications.

Strengths:

- Outstanding scientists at both NW and SW Centers.
- Development of novel methods (e.g. PBT) or analytic approaches (e.g. for assessing evolution of life history traits) that see direct practical application or that spur needed consideration of the long-term effect of selective fishing or hatchery domestication selection, etc.
- Apparent interest of managers to apply Sattethwaite's models of factors that influence whether or not steelhead elect to become anadromous, is probably a good example of how a fairly esoteric modeling exercise may generate useful and unexpected management applications.

I conclude with a comment on the proposed Epigenetics work that has just begun: I am too old to understand it, but it sounds pretty amazing if true. Unless I miss the boat entirely, epigenetics provides a possible mechanism that demonstrates that "environment" (viewed broadly) can cause genetic changes (through methylations) that may last through subsequent generations. All I can say is "wow"……..

Theme 10: Life Cycle Modeling

Full life cycle models theoretically incorporate understanding originating from research carried out under the previous themes, so it is logical for these to have been treated as a "wrap-up" topic. However, by this time at least one panel member was suffering from "Salmon Fatigue" and so his comments are less than insightful.

Strengths:

- The CV life cycle model seems designed very explicitly to deliver a product that would be exceptionally useful to guide water management and the components of the model seem very well identified. Continued work on the model seems highly desirable, with a focus on fry movements (largely unknown, but an important part of the model) and prey resources (to allow possible addition of bioenergetic considerations (?))
- The Columbia River life cycle model seems an excellent example of taking results from studies at smaller scales and applying them to a large scale LCM that is intended to allow assessment of specific management actions. This ultimate goal cannot be faulted.

Concerns:

- For both large-scale LCMs, it seems that "validation" and parameter estimation are critical issues, especially if there is an intention to have these models used for assessment of the relative virtues of alternative management actions. I am not qualified to judge how best to do this, but it seems obvious that large models with large numbers of parameters, often independently estimated, may generate highly uncertain outcomes that may not be sufficiently reliable to guide decision-making. How can one make that determination?
- With the Columbia model, I express concern (that may not be justified) that there may be a "one size fits all" ESU module that is not population-specific. Age-specific maturation and fishery exploitation rates of Chinook salmon are well known to vary across populations.
- In the Columbia LCM models, where models appear in part to be used to determine potential benefits of habitat alterations (e.g., recreating a meandering Catherine Creek), it seems to me that the context just begs for a cost/risk/benefit evaluation framework that is either currently lacking or was not presented. For example, although the benefits of recreating a meandering Catherine Creek may be large, it is also likely that the cost of achieving this new configuration may be very large and that there may be substantial

risks that the attempt to create this meandering stream may fail absolutely or partly, thereby diminishing the benefit that would be conjectured under an assumption that the restoration will work. An economist with expertise in cost/risk/benefit analysis should be added to this group!

Theme 11: Other Species

Reports on green sturgeon and Eulachon research were both fascinating. I was a bit less impressed by the rockfish work, perhaps because the sample sizes of collected fish seemed much too small and because it's always tough to know what can be done with recreational fishery statistics. It seems to me that work on green sturgeon absolutely must continue. Work on eulachon seems not quite so critical given the recent apparent "rebound, but who knows if that is setting a new trend. I believe that it is relatively common for highly productive species to exhibit extreme abundance variation immediately before they crash entirely!

Recommendations:

- Continued research on green sturgeon should receive highest priority because the estimated population sizes for the Sacramento, Klamath and Rogue populations are so small. If recruitment is poor in these populations, then the future is far from bright. Therefore, research focus should switch to capture and monitoring of juveniles produced in these systems.

Reviewer #2 Report on Program Review of Protected Species Science
Northwest and Southwest Regional Science Centers (West coast region)
7600 Sand Point Way, Seattle, Washington
4-8 May 2015

Background
The science carried out by NMFS on protected fishes in the West coast region has the over-arching goal of providing "the best available scientific and commercial data" for decisions influencing these species. This review pertains to 28 distinct population segments of salmonids, plus southern DPS green sturgeon, southern DPS eulachon, and three species of rockfish in Puget Sound, all of which are listed as threatened or endangered under the Endangered Species Act. Generally, protected-species science addresses ESA section 4 (listing, recovery plans, designating critical habitat, protective regulations and exemptions), section 7 (consultations regarding jeopardy, adverse modification of critical habitat, producing biological opinions), and section 10 (conservation plans, research permits, enhancement permits, reintroductions). These general categories do not have a simple one-to-one relationship with research needs, but they do illuminate that science to meet these needs may have to be immediately responsive (e.g. to determine jeopardy) or part of a longer-term effort towards improved ecological or evolutionary understanding. Research on salmonids in particular has likely benefitted from synergies in data available for fisheries, but the twin goals of salmonid protection and harvest complicate protected-species management, especially since protected and unprotected individuals may intermingle and appear superficially similar. As a consequence, the review panel was presented with a tremendous amount of information to evaluate and synthesize in comparison to what is typically known about protected species. (Sturgeon, eulachon, and rockfish are more typical.) In support of protected species management, scientists in the West coast region have had a range of research to accomplish, from on-going monitoring associated with updating status reviews, to hypothesis-driven research on controversial topics such as hatchery or predator effects, to fish genetics and population model development that have helped define these fields. In addition, the centers have excelled at crisis-driven research, including several instances in which research progress was made through foresight in advance of a crisis. There is undoubtedly some upheaval in resource flow accompanying crisis-driven research, but crises seem inherent for protected species and might as well be embraced as opportunity, not just challenge. I do not foresee that overall funding from the federal government for research on protected fishes is likely to grow dramatically, which brings up a potential need to determine when enough is known about a particular factor to reallocate resources to areas in which there is more uncertainty, variability, or opportunity for response.

General Observations and Recommendations
Do current and planned protected species scientific activities fulfill mandates and requirements under the ESA and MMPA, and meet the needs of the regulatory partners? (Are current science programs focused on highest information needs identified by NOAA Fisheries managers?)

- Strengths: I perceived general alignment between WCR priorities (presentation 1.1) and the scientific research reported in the presentations, with on-going research throughout the salmonid life cycle and excellent examples in which science has led to better practices (e.g., hatchery breeding programs and timing of release, improved fish passage survival rates, timing of barging, fishing regulations).

- Challenges:
    - One challenge is simply a function of the format of the three days of presentations, which is that the review panel did not have much access to the managers' perspective, so I am cautious in drawing a strong conclusion that science needs are being met.
    - Some information that seems highly relevant to management will be challenging to get, for instance understanding the consequences of 1000s of small-scale habitat restoration activities (and habitat-protection activities) in the context of best management practices and mitigation.
- Recommendations to address issue: Develop habitat/ fish monitoring guidelines and a database as an information repository, in preparation for meta-analyses in the future, and to make it more straightforward for people requesting restoration funds to build monitoring into their budget. Pursue proposed MBACI and retrospective comparisons (presentation 3.0) to define ecological value of habitat attributes.

Are there opportunities to be pursued in conducting protected species science, including shared and collaborative approaches with partners?

- Strengths: Collaborations exist between NMFS scientists and state and tribal entities, and extramural funding has substantially increased research scope.
- Challenges:
    - Collaborative work with fishers to collect genetic samples shows different stock representation than assumed in FRAM (presentation 7.1), which more generally points out that data collected in collaborative efforts may be difficult to incorporate into existing NMFS frameworks,
    - Substantial data relevant to protected species are collected outside of NMFS, for instance through a wide array of coded-wire-tag releases and recoveries. (Indeed, we heard that the federal government does not have responsibility for collecting data in freshwater.)
- Recommendations to address issue: NMFS seems like the proper entity with the big-picture perspective to provide a repository and clearinghouse for salmon-related data, and can implement a strategic approach to consistency and quality of data, and/or modeling approaches that take into account data quality through explicit incorporation of observation error.

Are the protected species scientific objectives adequate, and is the best suite of techniques and approaches used to meet those objectives? (Provide advice on the direction and quality of the data collection and assessment programs)

- Strengths:
    - Scientific presentations to the panel were impressive overall, as well as pointing to published literature from the science centers that has clearly passed the scrutiny of peer review.
    - WCR scientists have strong modeling capacity to integrate disparate data sources in a way that provides synthetic understanding and potential predictions given different interventions.
- Challenges:
    - I saw many different models during the presentations, some of which are bewilderingly complex

    - Salmonid populations likely show a wide range of relative rates of fecundity, survival in freshwater, and survival in ocean, with different levels of interannual variability. One example was provided for steelhead in SnowCreek vs. Sashin Creek steelhead, neither a protected DPS (presentation 9.0). I missed any general effort to collate vital rates by life history type and evaluate the amount of temporal variation and context-specificity.
- Recommendations to address issue: Of course, let people develop and use their own favorite model. But, it may be strategic to: 1) develop a list of the sorts of tasks (e.g., water management, climate projection) and inputs (e.g. linear/ nonlinear relationships, density-dependence, species interactions, single or multiple types of data regarding population size, gaps in data, Bayesian framework, spatially-explicit, plus error distribution, process vs observation error) for which people typically want models, so that it is obvious how different models compare across a common set of criteria; and 2) accumulate published models about salmon in some sort of database, even those that are not used regularly in management, with the objective of continuing to test those models with new data, to see the approaches and level of model complexity that continue to work successfully.

Are the protected species studies being conducted properly (survey design, statistical rigor, standardization, integrity, peer review, transparency, confidentiality, etc.)?

- Strengths:
    - Impressive scrutiny and peer review, as evidenced by how well NMFS science stands up in court and the number of peer-reviewed publications.
    - Presentations on hypothesis-driven short-term studies demonstrated clear and appropriate study designs (e.g., 3.2, 5.1, 8.2, 9.1, 9.2).
    - Although I did not see this covered explicitly in presentations, the summary for Status assessment and Recovery noted a successful "data compilation and management system." This seems like an important contribution, because data should be vetted and archived by a federal entity.
- Challenges: This question asks the review panel to draw conclusions at a level of detail that was not really possible to convey in a 3-day period, given the variety of projects going on.
- Recommendations to address issue: I was especially impressed by what can be learned from large-scale interventions and recommend using these whenever opportunity arises, e.g. hatchery on/off, fishery on/off, flow regime, dam removal, spread of impervious surfaces. These large-scale interventions are often unreplicated and without obvious reference systems, so NMFS can also lead the way in appropriate sampling designs and inference.

How are advances in protected species science and methodological approaches being communicated and applied in NMFS?

- Strengths: NMFS science is well published in peer-reviewed journals, and the WCR managers present at the review seemed generally satisfied with the responsiveness of scientists to their information needs.
- Challenges:
    - Barring 7.1, outreach to the general public seemed small, but in conversation with leadership, I learned that public relations and web presence have improved following a targeted hire.

  - Scientific output from models, for instance evaluating climate change risks or attributing mortality across the life cycle, may be at odds with manager needs in discussions about particular projects (e.g. 98% attraction and 95% survival through fish passage; or meeting escapement target).
- Recommendations to address issue: It may be helpful to clarify the process by which research results move to implementation, for instance, results from the science centers have a transparent process by which data, models, and effect sizes are translated to their use as best available science.

Key (Specific) Findings and Recommendations

Theme: Status assessment and recovery

Some protected species are still poorly known and require improved information on status and trends. These species are concentrated among the non-salmonids, and presentations in section 11 indicated that they are now better known than when they were listed. Apparently, there are still a few recovery plans to be completed for salmonid species, but I did not see that these were addressed in any of the presentations so cannot evaluate whether these DPS's are still poorly known and whether research is focused on filling gaps.

- Strengths: Recovery plans are complete for most salmonid DPS, and progress has been made in filling data gaps for non-salmonid species.
- Challenges: Northwest "crisis" science grew from the mid-1990s to mid-2000s,but funding has declined and hiring has stagnated since then.
- Recommendations to address issue: This issue of how to orchestrate a succession of expertise was a theme throughout the presentations, but I (like others) see no easy solution. Clear data management and archiving will be beneficial in terms of understanding when enough is known about one ecological component to be able to re-allocate resources elsewhere.

Theme: Monitoring and sources of data

My observations on this theme are already covered above in discussion of scientific objectives and methods.

Theme: Freshwater habitat science

Fish-habitat relationships are a convincing research need that will influence management in terms of both regulating human activities and prioritizing 1000s of restoration projects. I heard strong agreement that salmonids need sufficient access, amount, and temperature of water, but I did not feel there was a big-picture conclusion about whether these factors are still uncertain and need further testing, or attention should move to other factors (which may also be less important). Several presentations (2.2 and 3.0) indicated that substantial resources are devoted to monitoring programs for salmonid habitat and/or improved understanding of fish response to habitat characteristics, but I did not get a good sense of the "state of the science" – that is, what is known, and what still needs to be resolved. Finally, on this topic, It may be helpful to develop some guidelines on pre- and post-restoration monitoring that would help in articulating responses in terms of habitat variables and fish variables, would improve use of the monitoring in an eventual meta-analytic framework, and would make it more straightforward for project proponents to put monitoring and data access in to a proposed budget.

- Strengths:
    - A focus on process-based restoration seems valuable, that is, rather than adding structure, let the water do the work, and focus on water flow, access and temperature. NOAA has contributed to this effort through the "Stream and Watershed Restoration" book as a framework for restoration.
    - NOAA NMFS has a database on 1000s of habitat restoration projects.
    - NMFS leadership in monitoring the consequences of Elwha Dam removal is notable, and I strongly support learning from such large-scale restoration projects (presentation 3.1).
    - A number of presentations addressed sub-lethal, behavioral, or individual survival responses among salmonid responses to habitat characteristics (3.2, 5.0, 5.1, 9.2), which appears as a key science need in the WCR (presentation 1.1).
- Challenges
    - Both habitat restoration and habitat protection will need to be evaluated from a cost-benefit perspective to make effective decisions.
    - Information on sub-lethal and individual-level responses does not tie in neatly to the VSP criteria.
    - Habitats are monitored in only a subset of accessible waterways.
- Recommendations to address issue: Life cycle modeling clearly holds promise at integrating data sets and understanding consequences of different actions for salmonid DPS's. Opportunities may exist to increase the types of remotely-sensed data as part of monitoring habitat characteristics and change over time, even in non-wadeable streams.

Theme: Climate change

- Strengths: NOAA NMFS has begun building climate change considerations into recovery plans. In general, researching climate change in anticipation of greater effects in the future is a worthwhile investment.
- Challenges: Predicted warming and water availability may hamper salmonid recovery even if all interventions from a recovery plan are implemented.
- Recommendations to address issue: Broad access to down-scaled predictions on river flow and temperature will be valuable, without duplicating work in meteorological agencies.

Theme: River survival

- Strengths:
    - NMFS scientists have carried out excellent empirical studies, which have had real impact in changing practices (e.g. fish passage, barging).
    - Although I did not hear this from the presentations, I understand from other panel members that in-river survival studies have been standardized in CR tributaries because the CR BiOp requires that mortality from dams be mitigated in tributaries. Consequently, uncertainties in in-river survival are being resolved with consistent methods.
    - Recent work in the Sacramento is especially impressive in its documentation of low in-river survival and causes.
- Challenges: Some populations and locations are not easily examined for mortality sources, for instance from predation.

- Recommendations to address issue: As survival rates through fish passage structures are becoming better understood, this may be an opportune time to shift resources towards distinguishing predation mortality, for instance from non-native species and increased abundance of pinnipeds.

Theme: Estuary and ocean science

Many presenters expressed the sentiment that the ocean portion of the salmon life cycle is understudied, partly due to poor accessibility, but also because it is difficult to change what happens in the ocean. Ocean survival may also be among the most variable life-stage transition on an interannual basis.

- Strengths:
    - NMFS published evidence that estuarine habitat is used by salmonids, which has motivated substantial tidal marsh restoration and access
    - Ocean survival is important to collect each year.
- Challenges:
    - Measurements of ocean survival do not seem to be presented on a population-specific basis, nor in terms of whether protected and non-protected populations share ocean survival rates.
    - Measurements of juvenile spatial distribution in the ocean are difficult to fund.
    - Ocean survival may be evaluated from different source data including Bonneville returns, SAR, and CWT returns of particular stocks.
- Recommendations to address issue:
    - Evaluate whether juvenile salmon surveys could be combined with other fish surveys for economies of scale. Also, sufficient juvenile data should have been collected at this point to design a short-term (few-year) spatially- and temporally-explicit design that would test hypotheses about movement of different populations through the ocean, rather than requiring on-going work.

Theme: Harvest science

- Strengths: The panel members assure me that NMFS harvest policies successfully protect listed species. We did not hear much about protected species being killed as by-catch in fisheries, which may mean it is not a significant portion of mortality. The management strategy evaluation in presentation 7.0 highlighted effective ways to engage stakeholders and scientists in making rational fishing decisions.
- Challenges: Some challenges may remain in linking fishery interventions to improved VSP criteria for protected species, which would be valuable in terms of assessing costs and benefits of closures. This challenge is particularly acute if protected species are not possible to identify within the catch.
- Recommendations to address issue: Current assumptions about mortality rates may be possible to test with new inexpensive genetic techniques. Looking ahead, a plan for using both CWT and genetic information in adult mortality estimates is likely to be a fruitful area of development.

Theme: Hatchery science

- Strengths:

  - Presentations emphasized a strong, successful program to evaluate genetic changes in hatcheries and due to straying (e.g. 8.2).
  - Other work within NOAA has evaluated wild fish response following the shut-down of hatcheries in Oregon (I learned upon inquiry).
  - Epigenetic mechanisms that may interfere with hatchery fish ability to breed successfully in the wild are a potential new area of research (presentation 9.2).
  - DPS's that would otherwise be extinct have been maintained through captive broodstock (at some cost).
- Challenges: Nothing to add.
- Recommendations to address issue: Nothing to add.

Theme: Evolution and diversity

- Strengths: Strong, apparently collaborative group has been at the cutting edge of fish genetics.
- Challenges: The questions are not static, due to new life history types identified, and new emphasis on the costs and benefits of different sorts of life history diversity. I was initially surprised at the attention paid to anadromy vs residency in steelhead (presentation 9.0, 9.1) but then learned that this sort of genetic research is critical to making recovery plans for steelhead. The contribution of resident fish to anadromous DPS's has been contentious, so data are essential.
- Recommendations to address issue:
  - Challenge is really just a research need, and NMFS scientists seem excited about pursuing this angle, including long-term interest in heritability and new ability to map life history traits to chromosomal regions. Climate change provides a context for learning more about life history diversity, which may be essential to persistence through conditions that are warmer, drier, and more variable. This sort of work can be crisis-driven (to modify hatchery practices) or part of a long-term vision about research that will ultimately inform best practices in management.
  - Looking ahead, parent-based tagging (genetic methods) will become increasingly affordable, possibly replacing some coded wire tagging (at least for hatchery fish, so maybe not as relevant for protected species). It is worth planning for co-collection of genetic and CWT data so that the two types can be applied to decisions about protected species and fisheries management.

Theme: Integration across life cycle/ life cycle modeling

- Strengths: Protected fishes, especially salmonids, clearly experience different effects from human activities at different stages of their life cycle, and for a variety of reasons it is valuable to pursue an integrated approach to VSP. First, such an approach should better allow scaling up many small actions to a cumulative effect. Second, it enables comparisons across the life cycle in terms of interventions that would most help. Organizing data and uncertainty across the whole life cycle, then projecting consequences of different interventions, is absolutely essential to making informed decisions and recovery plans.
- Challenges: Through the presentations, the panel was exposed to many different whole-life-cycle modeling approaches, including emphasis on temperature-performance relationships (4.1) or flow-performance relationships (10.0), selection given tradeoffs between growth and survival (9.3), models linking smaller population models to larger ESU models (10.1), and

some forecasting models for subsets of the life cycle (6.2). I did not get a full picture on Management Strategy Evaluation, but it appears that may involve yet another form of population dynamics model (7.0). Which of these approaches work best?

- Recommendations to address issue: Continue to develop approaches to life cycle modeling, sharing and comparing these approaches by confronting them with how they perform as additional data accumulates.

Other protected species

- Observations
    - Strengths: More is known now about these species than when they were listed.
    - Challenges: Low hanging fruit has been studied.
- Recommendations to address issue: Focus on green sturgeon and methods to understand recruitment out of the heavily-impacted Sacramento River.

Theme: Invasive species

- Strengths: Invasive species are recognized by NMFS as part of what could influence VSP.
- Challenges: There is a big difference between invasive species in general being present and interacting with salmonids, and on the other hand making a convincing case of their contribution to VSP.
- Recommendations to address issue: Build invasive species work into evaluating consequences of habitat restoration (e.g. for knotweed) and monitoring in-stream survival (to quantify effects of non-native fishes).

Conclusions

Protected fish species represent a complicated management nexus of fishing and conservation, made more so by complex life cycles spanning many ecosystems. The scientists in NWFSC and SWFSC have tackled these problems with creativity, motivation, and capacity to both publish and provide useful results. In a flat funding environment, strategic allocation of resources is necessary – hopefully this review will provide some insight into how that could be done going forward. I also had two comments on the presentations, which may change what is provided in the next 5-year review process. First, it would help to frame each talk with an initial slide of specific management issues addressed by the research, and whether they are short-term, crisis, or long-term strategic. Second, it would be great to have presenters representing more diversity in gender and ethnicity. The faces of the scientists are the ones that implicitly tell others who is included in that group of experts. It seems fine to select presenters from among a research team as role models, showing that fisheries science matters to and can be accomplished by anyone.

Reviewer #3 Report on Program Review of Protected Species Science
West Coast – Northwest & Southwest Fisheries Science Centers
Seattle, Washington
4-8 May 2015

Background
On May 4-6, 2015, scientists from the West Coast Fisheries Science centers and associated laboratories presented summaries of research on protected fish species to an independent panel of reviewers at the NOAA Western Regional Center (Sand Point) in Seattle. Presentations followed an agenda organized around 11 themes with time for reviewers to ask questions. We were also provided with primary and secondary publications with additional information. My review of the protected species research follows the same organization, except that I address Non-native Species Research as a separate theme, whereas it was included under Theme 8 (Hatcheries) in the agenda.

General Observations and Recommendation
Overall, the work of the NW and SW Fisheries Science Centers has been excellent. The centers have excellent staffs. Not only has their work addressed the regulatory requirements for the National Marine Fisheries Service (NMFS) under the Endangered Species Act (ESA), but the pioneering work of the last 25 years at the Northwest Fisheries Science Center especially has influenced how conservation units are defined and recovery goals set for species internationally. The depth and bread of the centers' work have significantly advanced understanding of the factors affecting the viability of protected species. Both centers have an excellent record of publishing their work in peer-review scientific journals. Collaborations are strong. I have no doubt that the centers will continue to do outstanding work.

The development of life-cycle modeling is a great opportunity to advance the integration of scientific information into decision making and to integrate different parts of the science centers' programs. Presentations we saw show obvious potential of the tool but they also suggest some challenges. Because of their usefulness, these models are almost certain to proliferate as the tool is adopted by other groups involved in salmon recovery. This will lead to models where the structure and parameterization is done differently by different groups because the modelers may have different skills or the data and biological problems may seem different. Because of NMFS's expertise, the agency is in a unique position to translate, illustrate, and promote use of modeling methods and techniques that will help those developing the tools have a product that is as useful and scientifically sound as possible.

One aspect of integration that I did not see in this review was bringing social scientists into recovery science. Although I understand that social science is a different program at the centers and will have its own review, I strongly recommend cross-collaboration. Integrating social science into recovery is at the cutting-edge of conservation biology and can be very useful. For example, social sciences may help explain some of the unexplained variation in selection of salmon recovery projects (Jordan's presentation) that a focus only restoration techniques

(Roni'spresentation) cannot. From experience, I know that a recovery project might be selected for funding to gain a landowners' support for future work rather than because the project would deliver the most immediate or biggest biological response. Social scientists would immediately recognize this as a social capital strategy and could suggest how to measure its effectiveness, whereas natural scientists can only treat this as noise. There are many other examples. As the new generation of social scientists moves more towards synthetic reviews, randomized controls, and "big data" analyses, the perceived divide between methods of social and natural sciences that may have prevented collaborations in the past will shrink and allow creative, productive collaborations.

Nearly all the programs we heard about identified lack of funding or inability to use the available funding to keep and build long-term staff as a challenge. Many other organizations face the same challenge as restrictions on how moneys can be spent increase and opportunities to offer secure, long-term employment at competitive wages decreases. Although I am not knowledgeable enough about the opportunities and restrictions at NMFS to offer a solution, I will note that both fisheries science center campuses are located near major research universities. Although both centers and universities clearly collaborate now, looking to more, creative collaborations with these universities may be an important strategy in the future.

Key (Specific) Findings and Recommendations

Theme 1: Science Needs and Legal Mandates

Observations – The Panel heard two talks from staff describing 1) the structure and desired outcomes of the review and 2) the legal mandates that drive the science needs for the agency. The presentation was structured around the legal mandates of ESA sections 4, 7, and 10 followed by examples of science needs arising from those. Interesting, the examples of these needs were not organized using the same structure as NMFS adaptive management framework for Pacific Salmon (Crawford and Rumsey 2011) and the listing and delisting decision framework. Providing an organization like this would have helped me answer the first question that we were asked to consider "Do the current and planned protected species scientific activities fulfill mandates and requirements under the ESA..?" When I did match up the presentations on research to the delisting framework, it was obvious that two listing factors - disease and inadequacy of regulatory mechanisms - were absent from the examples of science needs and the focus of the following science presentations. I discuss this more under the Habitat theme.

- Strengths
    - Science centers understand both the breath and complexity of science needs and the difference between science and policy
    - Science centers deliver excellent analyses to inform ESA decisions
- Challenges
    - No transparent strategy for how to balance the demands to 1) provide the science and analysis to meet the regulatory needs of the agency and 2) advance understanding of species viability, threats to the species, and to develop better scientific tools to meet

these needs. Current balance appears to be the result different historical priorities and employee expertise. This may not be the best balance going forward.

- No transparent strategy for how to allocate research effort across the limiting factors. As noted early, we saw no work on either disease or on adequacy of regulatory protection (e.g., what is the trend in habitats protected by regulatory actions?). I suspect that the reason for not working on disease is different than the reason for not working on adequacy of regulatory protection, but I do not know.

Recommendations to address issue

- I strongly recommend using a transparent, structured decision making framework (e.g.,Gregory et al. 2012) to prioritize short-term and long-term science needs and determine the appropriate balance between regulatory needs and research. I also encourage NMFS to include recovery partners, such as the state agencies and tribes who use NMFS work, in appropriate parts of the process.

Theme 2: Monitoring and Sources of Data

Observations – The Panel heard talks on the development and organization of science for salmon recovery by the science centers and monitoring of salmon populations and freshwater salmon habitat. The different geographical scales, biological complexity, and distribution of different management authorities with different monitoring approaches across the region make this challenging. This has important implications for protected species recovery work. For example, although the Panel saw many examples of long-term population trends for different species of salmon, we did not see the same kind of data over similar temporal and geographical scales for habitat. I suspect this is because the challenges noted above have prevented collection of this data. These are challenges that NMFS can and should help overcome.

- Strengths
  - Investment in excellent scientists who focus on improving monitoring and monitoring designs. This helps fill a scientific gap that might not otherwise be possible.
  - Providing useful guidance and examples of monitoring designs and methods across different scales to help the many organizations actually doing monitoring provide useful salmon population and habitat data. One example we heard (although there were more in the literature provided to us) was the combination of land cover classification and geomorphic and climatic characteristics to identify where to focus in depth monitoring in a watershed that can be generalized to other similar watersheds.
  - Strong collaboration with agencies and tribes doing monitoring in some areas.
- Challenges
  - Collecting and analyzing data collected by different organizations using different methods and with potentially different levels of quality control and assurance.
  - Ability to detect trends in habitat quality and quantity is different for different ESUs. For some ESUs, this coverage appears to be very poor.
  - No apparent collaboration with agencies or tribes doing monitoring in some areas

  - Prioritization by funding agencies and/or science centers may be limiting monitoring to one set of questions (e.g. effectiveness of restoration actions) while excluding the other questions, such as the effectiveness of regulatory actions to protect habitat.

Recommendations to address issue

- Data quality clearly is a challenge. NMFS might consider using the five-year status reviews to highlight areas weaknesses in data and where data need to be improved in future.
- Better leadership by science center staffs to improve monitoring by collaboration with agencies and tribes where monitoring coverage is poor or where monitoring methods could be improved

Theme 3: Habitat Science

Observations – The Panel heard three talks. One was focused on research on habitat restoration; one focused on the NW Fisheries Science Center science support of the Elwha Dam removal; and one focused on toxic chemical contaminants and effectives on salmon.

Based on the habitat presentations we heard, almost all research and monitoring (with the exception of toxic contaminants) is focused on effectiveness of restoration actions. This is important work. However, this emphasis stands in stark contrast to monitoring and research for harvest actions, where regulatory effectiveness is at the crux of the evaluation, and for hatchery research, where recent advances in genetic tools, hatchery guidelines, and legal decisions will almost certainly drive evaluation of regulatory effectiveness. Most recovery plans identify regulatory tools that are expected to protect habitat (forestry, in-stream flow setting, growth management, shoreline management, etc.). Regulatory effectiveness is one of the key components of NMFS decision framework for listed species and a key component in its adaptive management framework (Crawford and Rumsey 2011) but it was not clear why this is not a focus for habitat research and monitoring.

- Strengths
  - Strong staff expertise
  - Strong scientific leadership in developing conceptual frameworks for how to use habitat assessments to guide recovery planning and prioritize recovery actions
  - Strong leadership in developing monitoring designs to evaluate habitat and responses of fish to different kinds of restoration actions
  - Strong leadership in researching and highlighting effects of chemical contaminants on salmon
  - Cutting-edge work in the effects of toxic contaminants on salmon
- Challenges
  - Little knowledge of effectiveness of regulatory actions described in recovery plans for habitat because little monitoring appears to be focused on this question
  - Collecting and using information on the effects of reach-scale habitat actions on fish at the population or ESU scale.

- Lack of a clear strategy (and adequate funding) to evaluate effects of toxic chemicals on salmon and link them to landscape and population level threats.

Recommendations to address issue

- Look for opportunities to evaluate regulatory effectiveness within the current monitoring efforts. If these do not exist, design these programs in collaboration with monitoring partners.
- Provide guidance to recovery partners on how to scale up reach-scale actions to population-level effects
- Work on a national strategy to evaluate and prioritize research on toxic chemicals that may be affecting salmon viability
- Focus on improving and implementing the recommendations outlined in Crawford and Rumsey (2011) for evaluating regulatory effectiveness

Theme 4: Climate Change

Observations – The Panel heard an overview of climate change research for salmon recovery and an example of how this kind of information could be incorporated into population modeling at the ESU and population level. We were also provided with additional written material.

- Strengths
  - Strong scientific expertise
  - Research that includes developing decision-support tools for effective management
  - Good cross-disciplinary collaboration and collaboration within and across the science centers
- Challenges
  - Increasing demand and corresponding lack of capacity to down scale climate models to be watershed specific so that planners can address and mitigate climate effects
  - Competing demands to evaluate climate change in terms of impacts on people versus impacts on fish
  - Incorporating climate effects into population models

Recommendations to address issue

- Develop a long-term strategy for balancing climate change research at NMFS centers and decision support for those implementing salmon recovery actions. NOAA has exceptional resources to inform climate change and making this information accessible and useful is a niche NMFS could fill.
- Look for opportunities to focus climate change work where it will meet dual goals of addressing salmon recovery and human health and safety
- Continuing exploring and evaluating how to incorporate climate change impacts into population models
- Look for opportunities to revise older recovery plans by incorporating climate change where it was ignored or not well considered.

Theme 5: Survival in Rivers

Observations – The panel heard presentations of two different case studies examining freshwater survival of salmon in rivers. One focused on research in the Columbia River and the other on the Central Valley of California. Although these are different situations, the differences were informative in terms of how NMFS designs and adapts research to answer questions about salmon survival. It was not clear, however, what was being done in other recovery regions and ESUs.

- Strengths
    - Good examples of hypothesis driven research
    - Both cases studies focused research on known threats to salmon survival.
    - Able to use the data to evaluate effectiveness of different recovery actions
    - Innovation, especially in the Central Valley research, in working around sampling and field challenges to assessing salmon survival
    - Good use of new technologies
- Challenges
    - Logistical difficulties in designing and maintaining consistent monitoring
    - Difficult to tease out the impacts of different stressors on the fish (e.g. dams, habitat mediated predation, pollution, etc.) and stressor reduction measures
    - Stability of funding to maintain and provide long-term data

Recommendations to address issue

- Continue to focus on collecting basic stage-specific survival
- Where possible use experimental manipulation of stressors in the system to evaluate their effects

Theme 6: Estuary and Ocean

Observations – The Panel heard three presentations. The first was an overview of ocean and estuary research; the second explored the development of ocean indicators that could be used for management; the third reviewed physiological measurements to assess growth and survival in the California Current.

- Strengths
    - Collaboration with other groups doing research on estuaries (Salmon River, Scott Creek, Skagit River) has highlighted the importance of estuaries to species life-history diversity and improving life-stage specific survival for some populations. This has been an important contribution.
    - Focus on exploring fish distributions in the ocean and ocean indicators could lead to better biological understanding and better models for salmon
    - Innovative cross-collaboration across disciplines, such as using physiological measurements to provide information on when density dependent processes are occurring in the ocean
- Challenges

- Ocean research is expensive
- Identifying useful, testable hypotheses and experimental designs for ocean research that could inform management actions. Because the biological and oceanographic processes offshore are complex and funding is limited, research can gravitate towards collecting nature history information without a clear design or idea of how and why to analyze the information. While the Newport Line work appears to have a focused intent, this is not obvious for the other surveys off of Oregon and Washington.
- Linking the information from ocean indicators to models and management decisions. It is not clear that the work:benefit ratio of this research will yield a useful product. However, this work is in its infancy and could be important.
- Collaboration on ocean indicator development appears weak.

Recommendations to address issue

- Provide a better explanation of the hypothesis driven framework for ocean research off of Oregon and Washington, including what we expect to learn and when.
- Develop better collaborations with others working on ocean indicators and modeling ocean conditions to forecast salmon returns

Theme 7: Harvest

Observations – The Panel heard an overview of the authorities and roles of different organizations involved in salmon harvest management, a case study of how scientific work influences the evaluation of harvest plans and NMFS's biological opinions, and a case study of a collaborative effort with troll fishermen to evaluate the salmon troll harvest

- Strengths
  - Strong international and regional decision making processes that rely to scientific information and analyses to adaptively manage fisheries.
  - Strong science center support for harvest analyses needed to make decisions
  - Clear incorporation of Endangered Species Act considerations in harvest management
  - Strong collaborative effort with stakeholders and recovery partners
- Challenges
  - Logistical, economic, analytical and political hurdles to changing to new methods of collecting population specific information for hatchery programs (e.g. to parental based tagging from coded-wire tags) and incorporating these into harvest management.
  - Figuring out how the genetic marking and troll fishery information might actually get used in harvest management
  - Improving parameter estimation and population viability models used in harvest management scenarios.

Recommendations to address issue

- Continue working on improving the data and analyses that can be used for harvest management. This appears to be an area where NMFS has a consistent record of scientific leadership.

Theme 8: Hatcheries

Observations – The Panel heard three presentations on hatchery science, including a case study of using hatcheries to recover Redfish Lake sockeye salmon; improvements in tagging and monitoring hatchery fish using genetically-based parental analyses; and an overview of the current knowledge about the genetic effects of naturally spawning hatchery salmon.

- Strengths
    - Strong scientific leadership for assessing the effects of hatchery salmon on wild salmon populations ranging from developing genetic monitoring tools to risk modeling frameworks to understanding genetic effective size.
    - Development of artificial propagation technologies for preserving unique, small populations of salmon. The investment in Redfish Lake was expensive but the knowledge gained has also helped prevent the extinction of a number of other populations.
    - Genetic monitoring tools are becoming increasingly cheap to collect and these data can be used to examine a broad set of questions
- Challenges
    - Incorporating the limited genetic information on effects of hatchery fish into population specific life-cycle models
    - Habitat-mediated ecological interactions of hatchery and wild fish are difficult to study and quantify
    - Balancing the long-term value of maintaining genetic diversity against the short-term value of increasing abundance
    - Ensuring that scientific design and rigor is incorporated into the suite of reintroduction strategies using hatcheries being considered by the NMFS regional office and recovery partners.

Recommendations to address issue

- Continue working on improving the data and analyses that can be used for hatchery management. This is an area where NMFS has a consistent record of scientific leadership.
- Focus more research on ecosystem interactions (e.g., habitat quality, species compositions, density-dependence) that affect hatchery and wild breeding success.
- Look for integration of the epigenetic work with hatchery research.
- Collaborate with Region Office and recovery partners on evaluating reintroduction projects.

Theme 9: Evolution and Life History

Observations – The Panel heard four talks addressing life-history evolution in salmonids. Compared to other work the science centers have been doing, this research is relatively new. The first presentation reviewed research on the genetic basis of life-history traits and the

implications for conservation of ESA-listed steelhead, the management of the Columbia River hydro-power system, and response to climate change. The second described identification of a potential genetic mark to distinguish the resident from anadromous life-histories in steelhead; the third described the beginning of epigenetic research at the NW Fisheries Science center. The fourth described a steelhead life-history model.

- Strengths
    - Good use of new genetic tools such as pedigree analysis to understand life-history traits such as migration timing and anadromy.
    - Good identification of applied research questions, such the cost of migration for *O. mykiss* relative to marine survival, the possibility of genetic rescue from climate change through life-history evolution, how to identify resident versus anadromous steelhead, and the potential for epigenetic variation.
    - Use of sophisticated modeling approaches
    - Development of user-friendly interface for life-history modeling to allow non-modelers to use the program
- Challenges
    - Maintaining these research programs long enough to see benefits. Sustaining the momentum of this program may be difficult if it always needs to rely on hitchhiking on other efforts to be successful. I am especially concerned about the work on epigenetics, which could be easily cut because it is new and the potential returns are unknown. Investing in this kind of new research, however, is one reason why the NW Fisheries Science Center has become a leader in salmon recovery science and other research laboratories have not.
    - Educating recovery practitioners on the importance of these concepts and results.

Recommendations to address issue

- Maintain funding for the epigenetic research program. Even a small, focused research program using the molecular tools now available has the potential to add large amounts of knowledge to what we know about salmon life-histories and to improve hatchery practices.

Theme 10: Lifecycle Modeling and Synthesis

Observations – The Panel heard two presentations on life-cycle modeling from the Central Valley and Columbia River. Overall, NMFS scientists consider life-cycle modeling as the framework for integrating all the research and results of studies being done on different aspects of salmon life-history and habitats to evaluate different recovery strategies. I support this approach.

Based on the presentations, it seemed like the models were developed somewhat independently with different groups making different decisions about how to parameterize and structure the

models or sometimes just adopting what others did. While it is important to allow innovation, it is also important that models use the best possible techniques and that the users understand how errors are propagated or dealt with in the model. For example, the Willamette model developed a metric for Total VSP = 4(Abundance + Productivity)+Diversity+Spatial Structure. This is innovative but I do not know what kind of biological support it has and how the properties of this metric affect the subsequent asserted relationship between Total VSP and extinction probability. Other groups might adopt this approach without understanding what it means. NMFS is in the unique position to promote the quality of the these modeling efforts by translating and illustrating more sophisticated improvements in modeling techniques to practitioners, encouraging good modeling practices, and providing critical support and review.

- Strengths
    - Consistent quantitative framework that can be applied everywhere
    - Strong collaboration among researchers using salmon life cycle modeling
    - Able incorporate and evaluate different recovery strategies and stressors on salmon
    - Able to integrate a lot of stuff
- Challenges
    - Can be very complex
    - Data to parameterize models are limited; no apparent consensus on how to extrapolate date from one area to another
    - Error structure of the models needs exploration
    - Requires modeling expertise for practitioners who want to use a model or interpret outcomes
    - Use of survival estimates may not incorporate sublethal effects on viability.

Recommendations to address issue

- Continue to bring science center expertise to collaborations to use and improve these models. Two areas that could be an immediate focus are in developing guidelines for how to use limited data to parameterize the models and examining the error structure in the models
- Involve other experts

Theme 11: Green Sturgeon, Eulachon, and Rockfish

Observations – The Panel heard three presentations describing how the science centers evaluated green sturgeon, eulachon, and rockfish species for listing under the Endangered Species Act and subsequent research. The common feature of this work is that all three groups of fish lack good historical or contemporary data on their distribution and biology. Little is known about the factors for decline for green sturgeon and eulachon. Harvest is thought to be the principal cause of decline in rock fish and it has been restricted.

- Strengths
    - Creative uses of a variety of analytical techniques to be able to extract useful information from the limited existing data
    - More knowledge now than before

- Challenges
    - Limited historical and biological data on all species
    - Lack of recovery goals and strategies
    - Not a priority for many management agencies

Recommendations to address issue

- Focus on green sturgeon research, including understanding migration and age structure, when the major sources of mortality occur in the life cycle, and evaluation of potential threats
- Explore collaborative efforts with divers to monitoring rock fish populations

Theme 12: Invasive Species

Observations – The Panel heard one presentation on science centers' work on invasive species. The science centers have limited staff devoted to this issue, although a variety of NMFS scientists identified it as a threat in discussion of in-river survival. Current work is focused on building awareness of the issue.

- Strengths
    - Focused analyses and good publications describing the distribution of certain invasive species; good use of existing data.
- Challenges
    - Large, biologically and politically complex problem to solve
    - Generally not the highest priority with most management agencies
    - High uncertainty in predicting outcomes of invasive species introductions or colonization.

Recommendations to address issue

    - Build technical collaborations with Invasive Species Councils to help with monitoring designs and potential responses when invasive species are found
    - Collaborate with other workers, such as the in-river survival or climate change studies, to build a strong invasive species component of the work

Conclusions

Overall, the centers have strong programs. Whereas I expected the NW Fisheries Science Center to have a strong salmon program because of its history, the expansion of the SW Fisheries Science Center into salmon and recovery science research is impressive. I look forward to the program continuing this work. Despite the challenges we all face in recovering these protected species, I left the review feeling excited by the quality of the scientists and the energy and dedication they bring to this effort.

Literature

Crawford, B. A., & Rumsey, S. M. 2011. Guidance for monitoring recovery of Pacific Northwest salmon and steelhead listed under the federal endangered species act. NOAA National Marine Fisheries Service, Northwest Region.

Gregory, R., Failing, L., Harstone, M., Long, G., McDaniels, T., &Ohlson, D. 2012. Structured decision making: a practical guide to environmental management choices. John Wiley & Sons.

Reviewer #4

Theme 1 Status Assessment and Recovery Science Overarching

- **Observations**
  - **Strengths**

- NOAA Western Centers (Centers) have been at vanguard of an extremely effective merging of science and management. They have successfully taken very complicated scientific concepts related to defining units of conservation and integrating these concepts into ESA policy and management. It is not an understatement to say these actions conserved 100's of populations within multiple DPS.
- Centers also developed a new approach to recovery science by designing the Viable Salmonid Population (VSP) framework. This is a simple, yet powerful, way to look at recovery as more than just one metric hinged on absolute numbers.
- Active participation in and leadership of regional teams is important as it puts science at the forefront of assessment and recovery teams. This has led to innovative conservation science.
- Ford and Lindley 2.0 presentation one of strongest themes for presenting overview of broader work integrated with big-picture priorities. Can see the contributions and influence of multiple staff and contractors.

  - **Challenges**

- The size of the science enterprise and the spread across 4 divisions seems to be a challenge to broader coordination.
  - This was apparent in "mixed signals" relative content presented for each theme in this review. Work across themes may be more coordinated than was demonstrated by materials presented but did not come through clearly.
  - The people in the organization got somewhat lost in the myriad of talks and the ultimate life cycle approach. Hard to see who (and how many people) does the work beyond the lead for many themes.
- VSP Policy needs to be approached more systematically to provide more standardized metrics across populations and scales. This will be an evolution but should be stated goal.
- Workload of over 2 dozen 5-year status evaluations is quite large and efficiency efforts to date while productive may be ready to move to a new phase.

  - **Recommendations to Address Issue**

- This is a core program similar to evolution and life history and overarching like life cycle model. Stability in the status review and support of recovery planning realms should be highest priority given impact on management.
- Efforts should be made towards an "Efficiency Initiative" to further standardize and leverage lessons learned in status reviews, status reports, and VSP management initiatives. The goal

would be more standardized status reports structures around VSP for status and the 4H's for threats.
- While the variability in ecology, population sizes, and geographic scope may make standardization seem difficult, a hierarchical approach to standards would work and this could be phases in with 1 or 2 of the 4 VSP elements in the current work-stream standardized this cycle.
- For next review, engage broader suite of science staff to better represent breadth of work teams.

Theme 2 Data for Monitoring

- Observations

Surprised by total emphasis on freshwater data and data by partners. Seems odd to not have discussed ocean data, yet later ocean research stated so essential.

- **Strengths**

- Collating, assembling, and storing large amounts of diverse data.
- Geospatial structure of data allows spatial examination of status and trends
- California's working frames statistical monitoring program seems like a strong development path. Oregon's work in these areas seems important as well.

- **Challenges**

- Datasets that are influenced by index stocks and index sites that may not be indicative of overall population or habitat trends.
- Seems like better integration of ocean with freshwater data is needed to streamline development of life cycle and stage-specific models.
- This was not mentioned but I would expect that give complex data structures significant population dynamics-type staff time is spent on data manipulation and query. If true, is there an initiative to provide data tools to simplify access?

- **Recommendations to Address Issue**

- Workshops and initiatives to support random sampling approaches to stream sampling and hierarchical approaches to spatial sampling.
- Support the development of methods for dealing with messy data.

Theme 3 Habitat Science

- **Strengths**

- Clear and direct connection to Habitat management needs – approach is broad and sweeping with high impact yet has focused case studies at local and watershed level.
- Clearly stated interaction across 5 teams from both Centers. Synergy of these interactions was most apparent in this theme.
- Program goals were clearly linked to key management needs – assessment, prioritization, and evaluation.
- Scientific method based 8 steps of adaptive restoration management is clear and focused and being applied by others. Science approach making a difference across country.
- Examples given for determining access and restoration priorities were compelling and informative. It would have been nice to have a big-picture summary of the number of watersheds evaluated and progress along 3 tiers.
- Connections to climate change resilience are clear and compelling.
- Elwha River project as a case study.
- Toxic Chemical Contaminant Lab – unique to agency and important in emergency situations, strong external collaboration network.

- **Challenges**

- Hard to identify root causes of habitat declines in some cases as there is a portfolio of threats impacting systems.
- The scale of the habitat and chemical pollution issue is enormous geographically and fiscally.
- Difficulty of evaluation of actions directly related to fish density and abundance.
- Toxins work almost always reactive instead of proactive.

- **Recommendations to Address Issue**

- Instead of trying to evaluate numerous habitat restoration actions, a focus on limited trial approaches to evaluation in just a handful of restoration types and habitats is encouraged.
  - More support needed for test cases – limited numbers, longer timescale:
    - Large Scale – Elwha- agency should work to secure funding for full long-term evaluation akin to LTER projects like Hubbard Brook
    - Restoration Types – culverts, woods, meanders etc. should have just a few representative studies.
- Most fish-friendly road crossings are much more climate resilient, this message should be strengthened and packaged through effective outreach and education. Useful to bring together National Weather Service into this effort.
- Mapping and modeling work is essential to setting priorities and needs to continue to expand in both improving methods and the application to watersheds.
- Breadth of toxin issues seems beyond the long-term capacity of the agency and may need to rely more on other federal partners EPA and define a narrower field of toxicology studies- one specialized fish-related system impacts on resource. Priorities needed.

Theme 4 Climate Change

- Observations

  - **Strengths**

- Clear and direct connection to broad-based management needs – approach is still in its infancy but is evolving and digesting a large amount of current findings into essential syntheses.
- Actions currently underway with geospatial analysis and modeling appear to be targeted towards identification of climate change refugia for priority protection.
- Integration of climate change into recovery plans is ongoing and important.
- Implementation of a West Coast Region Climate Team seems like foundation for communication and targeted R&D.
- Case study of Salmon in Columbia River Basin – it was extremely refreshing to see meta-analysis and synthesis of science on such a large scale and routine (annual) basis. With the volume of material being produced by this program and others in the region syntheses of these types are extremely insightful.

  - **Challenges**

- Varied public and political attitudes toward urgency and impacts of climate change.
- Changing nature of river systems from snowpack dominated water storage to rain dominated systems will change nature of hydrograph. Shifting baseline issue.
- Continued human population growth will likely impact and increase water needs throughout the region but especially in the southwest coastal and central valley.
- The size of the West Coast Region Climate Team could become a challenge to effectiveness but it seems important to bring in other NOAA line offices. Note: it is difficult to find output of this team in a simple Google Search!

  - **Recommendations to Address Issue**

- Continue evolution of integrating climate change into salmon recovery plans and, as necessary, status reviews. Would be reasonable that many of the metrics of this analysis would be common across the region but spatially and elevation specific as well. Efforts to share common global scale baselines and projections would be useful across country and regional metrics should be shared across coast.
- Climate Change Vulnerability workshops and assessments are important to salmon conservation because within this platform NMFS can draw upon expertise from other agencies, universities, etc. to provide stronger advice and solutions to foster resilient salmon and other fish populations.
- The "Restoring Salmon Habitat for A Changing Climate" initiative is an exceptional synthesis of information into a digestible scientific framework. An important next step is implementation at a local community level.
- There is great opportunity here to connect salmon to healthy and resilient infrastructure and local place-based decisions. Integration with outreach and communication essential. Salmon

fatigue may be countered by making salmon barometers of healthy waterways/landscapes – issues important to more people.

- The annual climate science review is an excellent approach and should be sustained; it broadens our understanding of these issues as salmon are an excellent synthesizer across local, regional, and global terrestrial and ocean impacts. Encourage use of ensemble models given multiple competing projections of future. Again, bringing this information to the public would be of great service.

Theme 5 Survival in Rivers

- Observations
    - **Strengths**
- Clear and direct connection to Hydro management needs – approach is targeted and has had high impact towards fish conservation.
- Providing quantitative data needed by managers to evaluate impacts of hydro (Columbia River 20 years of PIT data) and water storage/diversion (Central Valley acoustic work). Information is in direct response to management needs and setting quantitative performance standards.
- Multi-scale examination of survival with studies to estimate parr to smolts from headwaters (Columbia in ID and coastal CA streams) through complex river, drainage, and agricultural, systems through estuary to Ocean. Starting to understand complex processes like the dichotomy of higher density and smaller fish versus larger fish with smaller individual production. First steps in understanding what is optimal, adaptive, and ultimately resilient.
- Real world monitoring and solutions
    - Mainstem Columbia River studies, direct implications for management studies of barging versus river-run. Strong example of adaptive management. Documented spill effect – very important with temperature modest with flow – ability to increase S with these data
    - Complex analysis – integrating habitat with predation (introduced predators) Sacramento Bay/Delta work. Adding bioenergetic projections to evaluate impact potential.
- Research and development to create and refine tools needed for quantitative evaluations across different habitats. From original PIT systems in Columbia to recent initiative for PIT systems in non-hydro environments in Central Valley. Creative thinking outside the box - tethered smolts with GoPro monitoring. Teams have taken much work from feasibility to routine monitoring.
- Centers drove the project "success metric" to be optimized for returns not just out-migrants. Key to long-term stability.
- COMPASS model with state-based survival probabilities looks promising. While other more complicated models are emerging (and being developed within the Centers), this approach seems key for the next 3-8 years.

- **Challenges**

- Columbia River – massive hydropower infrastructure and balancing multiple water users.
- Sacramento massive economic impacts water transport and storage issues supporting an agricultural industry worth $40B and a salmon economy of $25M, leads to conflicting demands on water.
- Columbia and Central Valley different impacts in rivers (hydro dams vs rim dams) but similar estuary and delta impact with complex freshwater and salt marsh wetlands being channelized and diked. Need to partition these systems as human impacts and population dynamics impacts great.
- Some key predators protected by Marine Mammal Protection Act (sea lion and harbor seals); science shows predation by these animals has increased.
- Capacity Issues – for many of these programs and projects there is one lead scientist and maybe 1-2 support staff. This leads to key work and knowledge capitalized in student, post-doc, and contract (e.g. temporary staff).
- Stated explicitly in this theme but apparent in other themes as well - science enterprise is being heavily loaded by external funding in three ways: 1) expectations of funding entity; 2) time spent securing these funds and 3) time spent administering these funds.

- **Recommendations to Address Issue**

- Smolt Adult Returns (SAR) are essential metrics and much has been done but given knowledge base of losses at dam and losses in estuaries integrating these into adjusted SAR to look at coastal ocean and true at-sea survival seems prudent.
- While the paradigm shift to success metrics being based on SAR is important, the next step is understanding the impact of these systems and decisions on fitness – that is how are the offspring of these fish producing. While evaluation of this may be a long way off for some systems, studies should be designed in those that look closest to supporting substantial wild production soon and monitor fitness in these systems.
- Try more adaptive approaches – Like the concept of surrogate wetland habitat – rice ditch may produce bigger smolts than river and if abundance is great possible win-win solutions to produce fish from the rice growing areas as "artificial" floodplains
- Continue to advocate and produce science that integrated metrics of both downstream and upstream survival as metric of success – full cycle – essential and shows big-picture view (again ultimately need to link to population fitness).
- Relative to external funds – charge support personnel to minimize administrative burdens on all science staff.

Theme 6 Estuary and Ocean

- Observations
  - Strengths

- Clear and direct connection to Habitat management needs related to estuary science support of restoration projects – approach is targeted and has potential impact towards fish conservation.

- Estuary science programs helped foster better understanding of role of estuaries salmon habitats – estuary dependent life history thought unimportant to marginal – learned it is important for several ESUs and certain life history types (a nursery not simply a corridor).
- Documentation of massive changes to estuary habitat and potential impacts of these changes on salmon productivity is now a recognized need.
- Ocean sampling and work on indicators is starting to provide information to understand role of ocean conditions on salmon and context of recovery actions.
- Starting to partition Ocean Black Box - SWC-upwelling ecosystem and NWC- Plume and upwelling as ecozones. Differential ocean habitat use is now emerging as critical aspect of population diversity. These stock-specific patterns in ocean habitat use suggest partitioning of marine food patches by genetic portfolio.

  - **Challenges**

- Estuary impact information presented focused largely on large systems – important to document use and repair and conserve smaller coastal river estuaries was well.
- Estuary evaluations meeting management needs with basic science related to monitoring effectiveness of restoration actions but have same challenges as in freshwater habitat towards understanding if actions are increasing production at a population level.
- Ocean science has weaker linkages to management outcomes which influences some panel members understanding of utility. That said, NMFS and other science have indicated the importance of both tracking and better understanding this threat.
- Much work to be done towards understanding mechanisms by which ocean indicators act.
- Funding for Ocean Salmon Transects from WRO, Centers, and external is becoming limited, ship time funded by external funds. MSA needs for other fish take up ship time. Centers used to sample May, June, and Sept now only June. Lose ability to look at steelhead because head offshore by May
- Overcoming the "so what" factor. Perception that ocean issues cannot be addressed so why study. This was evident in this panel. However, liked the point that Ocean survival varies by factor of 25 and in-river by factor of 2.5. Ocean is key importance.

  - **Recommendations to Address Issue**

- Consider combining ocean and harvest science themes into an integrated data, modeling, and analysis system. Make strong linkages with broader stock assessment science.
- Essential to continue to partition SAR between river, estuary, and true ocean loss.
- NOAA is only agency with mission and capacity for large boat science but need to address shortage of funds and expense of large vessel time. Likes Hayes suggestion to develop ecosystem cruises to partner with other braches to study salmon as part of entire ecosystem. Integrated ecosystem surveys to get better science overall will mean all groups compromise.
- To leverage cruises need to determine suitable scope and capabilities of other ocean science platforms–telemetry networks, hydroacoustics, coo-op research gliders, AUVs, etc. These are likely better tools to answer many questions.
- Estuary work cannot ignore introduced species in evaluations- are shad juveniles/adults competitors to native fish. Dams allow adaptive management by shad removals.
- Address recurring theme of scientist capacity used for grantsmenship and budget analytics.

Theme 7 Harvest Science

- Observations
    - **Strengths**

- Clear and direct connection to Harvest management needs – approach is targeted and has had high impact towards fish conservation in a complex regulatory environment.
- Integration of conservation science into Pacific Salmon FMP regulatory umbrella. Seem to be effectively balancing MSY, hatchery production, and ESA conservation for these mixed-stock fisheries.
- Provide key and timely science, technical and analytical advice for control rules
- Ocean Salmon co-op research formed effective stakeholder partnerships and novel (and important) data streams.

    - **Challenges**

- Classic mixed stock fishery but with extreme similarity of appearance issues and ESA context. Appears to be weak management controls of mixed stock fishery, more analytical power is needed.
- Differences between commercial harvest GSI samples (with only 90% assignment rate) and current FRAM model (based on CWT results) create a challenge and an opportunity. Because view of mixed-stock harvest is not consistent – presents a new and potentially insightful challenge to finding out what drives the differences and what it means to ocean ecology and harvest.
- Fishery restrictions needed to protect stocks often reduce data and increase difficulty of understanding listed fish at sea.

    - **Recommendations to Address Issue**

- Need to develop a succession plan of active mentoring and career overlap in this theme because of all themes overlapping scientific careers important for harvest.
- Follow-up on ideas presented for synergy of cross-group work teams with risk assessment folks to analyze data in salmon content (e.g. killer whale example) and combined teams with stock assessment groups might also be of use.
- As noted above, integration with Ocean Science themes would be helpful. This may provide additional modeling talent, more incorporation of environmental variables that would enable better understanding of natural mortality leading to better fishery forecasting.
- Start to look at impact of environment on stock-specific migration routes to adaptively protect threatened and any weaker stocks.

Theme **8 Hatchery Science**

- Observations

    - **Strengths**

- Clear and direct connection to Hatchery management needs – approach is targeted and has had high impact towards fish conservation.
- Demonstrated ability to bring fish back from the brink with the Redfish Lake Sockeye – global example of science-based conservation.
- Science group has not only identified problems with hatcheries but also worked to provide sustainable solutions. Group demonstrated broad across and between Center collaboration.
- Access to internal skillsets in conservation science, genetic impacts, and animal husbandry are unique. Experimental hatcheries are part of Science Infrastructure and provide reality checks to limitations of people and systems.
- Key contributors to science in support of Hatchery Scientific Review Group

    - **Challenges**

- Expense of hatchery infrastructures and maintaining highest standards of fish health and environmental impacts.
- Evolving hatchery methods will always require new evaluations.
- Impacts on outputs of mitigation hatcheries and conflicts among needs lead to large amounts of conflict and controversy.
- The size and scope of hatchery programs allow ability to do large-scale experiments but reluctance to manipulate at these more meaningful scales.

    - **Recommendations to Address Issue**

- Continue course as leader in both identification of problems with hatchery systems and products and finding solutions.
- Essential to maintain momentum on consensus approach across tribal, state, and federal agencies.
- Leverage new technologies to make genetic tools cheaper and faster while ensuring quality control and assurance. Make sure to keep balance of capacity needed to generate data and analytical power to use these data.
- Considering how quickly hatchery influences can start and end, consider more aggressive use of 1-2 year pulses of fish to examine ecosystem interactions in an experimental frame that may be 8-10 years in duration.

Theme **9 Evolution and Life History**

- Observations

    - **Strengths**

- Important connection to both Hatchery and Habitat management needs – approach is among the most basic science that the center is doing and has potential to provide highest gains.
- One of strongest themes for presenting overview of broader work integrated with case studies. Can see the contributions and influence of multiple staff and contractors.

- The science and integration of science into both management and national policy makes this program world class. This program changed and continues to shape the approaches to conservation taken nationally and globally.
- The development of technologies and methods and the rapid adoption of emerging technology have allowed the Centers to better document, catalog, and protect salmon diversity – the building blocks of recovery and climate resilience.
- Working to develop objective genetic diversity and natural selection influences upon individual fitness and long-term species resilience. This is forward thinking and cutting edge.

  - **Challenges**

- Epigenetics – new field and some risk with expanding into this niche. Additionally, biometrist expertise needed for this subfield is uncertain in the long-term since person is a contractor.
- Basic monitoring and evaluation require intensive sampling and access.
- Genetic basis of O mykiss residency and anadromy in populations with full sea access.

  - **Recommendations to Address Issue**

- Program seems the most stable relative to staff to temporary ratio and this stability should be maintained if any restructuring occurs. This is a core program similar to general recovery science.
- Developing epigenetics capacity further has risk but likely worth expanding into this niche but it is important to commit resources to the analytical end of this sub discipline to gain most value
- Basic monitoring and evaluation functions should be conserved.

Theme 10 Life Cycle Modeling

- Observations

  - **Strengths**

- This theme is the most synthetic to management needs as it has the potential to integrate across all 4 H's as well as ocean science. In addition, the potential to balance a management portfolio is very high (e.g. multiple pathways to improve survival can be tested).
- Actively addressed a legal mandate to create life cycle model. This mandate was met.
- Current approach is very complex and is working towards full integration of all Centers and partner output data.
- Clear and direct connection to Hydro management needs – approach is targeted and has had high impact towards fish conservation.
- The Central Valley Chinook Life Cycle Model –CVC- LCM seems to be a strong example with the explicit modular design and the stated goal to start simple and add complexity as needed including understanding migratory corridors through transition and stage-based modules.

- SESAME model dynamic energy budget – use sport science to look at fish on water treadmills with increased flows- shows innovation.
- Strong information flow design where models go to science realm for review then adapted for use of management. Seems to provide framework for adaptive management to make improvement at any survival stage and understand potential response at population level.
- The two larger modules (population and ESU) in the life cycle approach are compelling as the population level model has the potential to be very prescriptive in habitat restoration and applications to spatial diversity while the ESU module can be prescriptive of dams, estuary, and ocean impacts.

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- **Challenges**

- Legal mandate as a forcing mechanism for one of the models being developed could create a challenge with both future timelines and legal precedents (real or perceived) that could potentially occur. This could limit future creativity.
- Balancing between available data, model complexity (right balance) and competing overarching modeling approaches (more traditional approaches and new methods with state-space models in a maximum likelihood framework).
- Efforts do not appear to be well integrated within and across Centers. High risk and high gains.
- Modeling efficiency of a simple model versus real management need to have geospatial panes in the modeling structure.
- Dependence on contractors and building capacity through temporary employees – overcoming "drought emergency mentality" to build a permanent research, development, and support infrastructure.

- **Recommendations to Address Issue**

- Given importance and use of these models to managers in threat analysis and alternatives decision-making, it is essential that managers are included in model development especially in determining: 1) spatial scope; 2) output stages; and 3) capturing and understanding modeling error.
- Establish a modeling working group to work on standardized approaches to model building that allows evolution from a loosely organized group of life history models into shared frameworks
  - Create common conceptual framework like population and ESU schematic
  - Work towards a common currency of outputs at selected stages
  - Work towards standardized approaches built in a nested spatial and model complexity hierarchy.
  - Challenge is to a working group is to formalize approach without restricting creativity and application to local needs.
- Leverage resources across programs and at both (all?) Centers to build capacity for model development in permanent work staff.
- Work toward reducing internal modeling needs for "input data streams" by better leveraging information and datastreams from other agencies (e.g. NOAA weather service river forecast

scientists; NOAA climate office, etc.). In short, any efforts to "outsource" input environmental datastreams from other partners are encouraged.

Theme **11 Green Sturgeon, Eulachon, and Rockfish**

- Observations
    - **Strengths**
- Work that is being done on limited resources is leveraging opportunities to gain core information. Doing the right science to get core information.
- Work is creative in both field approaches taken and modeling to gain maximum information for limited data.
- The vision (foresight) to model movement data to get preferences then ocean habitat use, work with these data to get habitat areas

    - **Challenges**
- Long life cycle of green sturgeon and very short cycle of eulachon.
- Sturgeon population dynamics – difficult to evaluate reproductive success.
- Eulachon and rockfish significant data gaps.

    - **Recommendations to Address Issue**
- Continue innovative and cost-effective work illustrated in review – important for Centers to find resources and/or partnerships to continue due diligence level programs.
- Work to secure agency funding for improved science on these species – would be good to develop a structured and tiered plan of science needs jointly with managers to have a "shovel-ready" proposal. There is an opportunity here to leverage the extreme life cycle difference of eulachon and sturgeon into a bracketed research and science approach.

Theme **12 Nonnative fish research**

- Observations
    - **Strengths**
- Identification of potential importance in food webs
- Science in general recognizes potential negative impacts of invasive species.

    - **Challenges**
- Underappreciated role of these fish in estuary and marine ecosystems
- Role of non-natives as important game fish for fisheries while ecologically are both predators (pike, smallmouth bass, walleye, striped) and competitors (brook trout, rainbow trout, shad) with endangered salmon populations
- Duplicity of management efforts in region encouraging non-native predators while actively reducing native pike minnow impacts

- Impacts hard to study and data limited. However, California is especially challenged with invasive species – striped bass to Asian clams to aquatic plants. Drastic change in fish community to 75% centrarchid!
- Non-natives not just fish but diseases, invertebrates, and plants.

  - **Recommendations to Address Issue**
- Continue to follow approach to "hitch" non-natives to other hot topics and priorities- work with these groups to get more data and attach to larger projects.
  - Leverage demonstration type projects that have been completed by students or postdocs to demonstrate importance
  - Leverage studies like SWFSC – where non-native predators were an issue and stakeholders became interested in study of interactions between water, structures, and invasive species.
- Perhaps a more sustainable approach would be to integrate "nonnative fish staff" within an ecosystem group. The point being that cross-species interactions are about structure and function not necessarily species.
  - Ecosystem predation studies should include pike minnow, black bass, and walleye – combine adaptive management with ecosystem studies. Climate change related predation work should go here as well

Reviewer #5 Report on Program Review of Protected Species Science
West Coast Protected Fish Species Program Review
NMFS North West and Southwest Fisheries Science Centers
Seattle, WA, 4-8 May, 2015

I. Background

This report summarizes my observations and recommendations regarding the scientific activities of the NMFS West Coast Protected Fish Species Program (WCPFSP) carried out by the Southwest Fisheries Science Center (SWFSC) and the Northwest Fisheries Science Center (NWFSC). My observations are largely based on information presented by NMFS scientists and leadership to a review panel on May 4-6, 2015, i.e. they represent what I heard as a member of this panel. Additional information came from discussions during the three meeting days and from relevant publications and other documents referenced in presentations and in the meeting agenda. The overarching purpose of the review was to evaluate if the WCPFSP is doing "good science" and "the right science." Reviewers were asked to consider 5 general questions regarding opportunities, relevance, credibility, legitimacy, communication, and applications of WCPFSP science.

II. General Observations, Recommendations, and Conclusions

The breadth and quality of the information presented to the review panel make it clear that overall, the WCPFSP is a highly productive and in many cases cutting-edge scientific program with world class scientists. The program delivers credible scientific information in support of NMFS west coast fish protection mandates under the ESA and the Magnusson-Stevens Act, especially regarding salmonids. The contrast between the advanced state of salmonid science and the much more limited data and information about the three other protected fish species covered in this review is striking. Similar to the other panel members I was, however, impressed by the amount of scientific progress that has been made in a relatively short amount of time with regard to green sturgeon, eulachon, and Puget Sound rockfish species - it seemed that relatively little funding really went a long way. Securing more funding is clearly essential for answering more difficult questions about how to protect these species. This is particularly important for green sturgeon because its abundance is very low. One way to accomplish this might be to more systematically leverage existing studies on other species to also answer questions pertinent to these species. This might also help better understand fish communities. By design, the WCPFSP is focused on individual species to fulfil mandates and requirements under the ESA, but species cannot be understood or managed on their own; the community and ecosystem context is important. Another way to secure more funding and/or reduce internal NMFS costs for work on additional species and communities is a more strategic pursuit of external funding and collaborations with State, tribal, academic, local and private entities, including "citizen scientists."

The presentations given during this review were generally very informative. More complete information about staffing and about NMFS adaptive management and decision making

frameworks that integrate science and management would have been helpful. It would have also been helpful if all talks had included clear statements about how the science presented is or could be linked with management applications over the short and long term and if they had more consistently presented and discussed strengths, challenges, and opportunities. Finally, I would have also appreciated presentations by and discussions with some early career scientists.

In my opinion, the greatest strength of the two science centers is their highly capable, engaged, and innovative scientific staff and leadership. Contract staff and collaborators at universities and elsewhere also play an important role in the Centers' science activities. Together, these scientists provide an impressive breadth and depth of scientific expertise to NMFS and the nation. Center leadership has succeeded in maintaining a functioning, though somewhat reduced, workforce through difficult financial times and under mounting political pressures associated with species protection. Hiring and financial constraints as well as an aging staff present a challenge to maintaining this workforce and its current high level of productivity, expertise, and substantial institutional memory into the future. Judging solely by the NMFS staff present during the review, another staffing issue may be underrepresentation of women and minorities, at least among the higher level staff. Federal funding for the WCPFSP has recently shifted from a period with increasing funding and center growth to the current period of overall flat or declining funds and very little hiring. Reimbursable funding is an important component of the annual budgets of both Centers; up to about one third and sometimes more of the total budget for the NWFSC appear to come from reimbursable funds.

NOAA currently does not hire permanent staff with reimbursable funds. One reason may be the risk of reimbursable funding disruptions. However, losing well trained and/or highly qualified non-permanent staff also presents substantial risks. For example, important expertise and investments in human capital may be lost and succession planning is difficult if early career scientists are hired mostly into short-term positions. It seems unlikely that congressional budget allocations will substantially increase any time soon, while reimbursable funding can be maintained and even increased through active Center efforts to develop projects with other Federal, State, tribal, and local entities. Reimbursable projects with cooperative partners tend to also make the scientific work by Federal agencies more immediately relevant to State, tribal, and local entities and strengthen cooperative and collaborative partnerships. With active management, this type of funding is no less stable and reliable than congressional budget allocations[1]. A "diversified portfolio" of reimbursable projects with a variety of funding sources is also a hedge against abrupt funding cuts by any one source – it is, for example, unlikely that all partners would experience the same amount of "salmon fatigue" at the same time, and some would likely never experience it at all. USGS water science centers show that it is possible to maintain and even grow large and highly productive Federal science centers with many high level scientists almost entirely on "soft money" through cooperative partnerships. While maintaining and obtaining more adequate levels of Federal funding for protected species science needed to fulfill NMFS' mandates under the ESA is clearly a priority, I also recommend

[1] See figure on page 2 of "NWFSC Annual Guidance Memorandum for Fiscal Year (FY) 15"

reevaluating the use of reimbursable funds for permanent NMFS staff salaries, perhaps especially for entry level positions. I believe a substantial reimbursable program should be viewed not just as a challenge, but can also be viewed as an opportunity to strengthen Fisheries Science Center resilience and health and add much needed permanent staff.

Another major strength of the two science centers and the WCPFSP is the generally high level of scientific quality and credibility of the information produced ("good science"). This is a result of the high caliber, world class scientists at the centers and strong efforts to maintain and improve the quality of the science through publication of results in high-quality, peer reviewed scientific journals and a high level of interaction by center scientists with their peers at scientific conferences and through collaborations (training likely also plays a role, but was not specifically mentioned). Systematic reviews of NMFS fisheries science programs initiated in 2013, including the present review, are intended to further improve science quality and credibility. These reviews will be repeated every six years and involve an external expert panel. I believe these reviews will provide important feedback and add to the scientific strength of the WCPFSP. They are also a good opportunity for center staff to network with their colleagues and learn more about their work. This opportunity would likely be particularly important for early career scientists, but very few were present. Reviews of large programs such as the WCPFSP have to balance scientific breadth and depth; the larger the program, the more difficult it is to do any in-depth reviews of specific topics. Journal peer reviews tend to deliver good in-depth feedback on specific topics. The 6-year panel reviews should perhaps be more clearly aimed at higher level issues. NMFS could also consider adding review mechanisms for narrower topics of special concern or even ongoing center- and regional-level reviews similar to reviews conducted at USGS water science centers. These USGS science centers employ review "specialists" whose job it is to review scientific data and information generated by center scientists. They also review all scientific projects from the proposal stage through implementation to reporting of results on an ongoing basis. In addition to these center-level specialists, the USGS also has regional and national-level reviewers who have to approve all scientific proposals and conduct comprehensive program reviews that are repeated every three years as well as additional topical reviews. Because these reviewers are USGS staff, there are no FACA concerns. Clearly, employing these review specialists and implementing so many reviews represents a large time and money investment, but the USGS finds that the benefit to data and information quality is well worth the cost. I recommend that the already initiated program reviews be continued, that more early career staff be included in the reviews, and that additional reviews on narrower topics be considered.

I also appreciated efforts to make WCPFSP science relevant to regional and national NMFS management, consultation, and conservation efforts regarding protected fish species ("the right science") and coordinate with resource managers. Relevance to resource management plays a very large role in setting the scientific agenda for the two science centers as evidenced by the (commendable) Centers' Strategic Science Plans. Relevance with regard to ESU viability assessment and evaluation and treatment of threats was also used somewhat loosely as a framework for organizing the salmon section of the WCPFSP review and the WCPFSP has clearly made great contributions to protected fish species management. However, while all

information presented to the panel could be potentially useful to NMFS managers, it was not always clear how the information had been or was intended to be used by NMFS managers. It was even less clear if and how State, tribal, local, academic, and private entities use WCPFSP data and information, and only few examples were presented about how results are communicated outside of scientific journals and within NMFS. There were no representatives from partner agencies or other data and information user groups among the presenters or in the audience, making it difficult to assess their satisfaction with NMFS science products without additional information. Clear science-management linkages should be a requirement for all WCPFSP projects. Feedback from a large variety of partners who use NMFS data and information could and perhaps should be sought as regularly as a feedback from scientific expert panels. It may also be worth working with social scientists to more systematically study science needs of various science user groups in more detail and assess the relevance of NFMS science as perceived by various user groups. Economists could provide information about the economic feasibility and repercussions of management options (e.g. various habitat restoration and species protection options) derived from WCPFSP information. NMFS employs economists, but their results were not presented. I don't know if NMFS employs or works with sociologists. I recommend inviting additional NMFS data and information users from within and outside of NMFS to NMFS program reviews and/or providing other opportunities for their feedback. I also recommend considering closer interactions with social scientists and economists.

I was a bit surprised that adaptive management (AM) was not mentioned very often. I view adaptive management primarily as a systematic way to link and integrate modeling (both conceptual and quantitative), monitoring and research, and management and to articulate clear management goals and scientific uncertainties and hypotheses along the way. The active form of AM also provides a good framework for experimentation and collaborative adaptive management (CAM) brings in stakeholders and strengthens interactions with collaborators and cooperators. Along with the other review panel members, I struggled with understanding the linkages among the different projects that were presented and the linkages among projects and management applications. It was also often difficult to assess project contributions by and benefits to others. Embedding the projects more clearly in an AM framework could clarify and strengthen these linkages. The Columbia River Adaptive Management Implementation Plan provides an example, but was barely mentioned. I was also a bit surprised that decision making frameworks such as structured decision making were hardly mentioned at all. They, too, could be used to clarify science-management linkages.

I thought it was interesting that a large of amount of work is taking place in freshwater and estuarine habitats compared to a relatively smaller amount of work taking place in the ocean. There are many other agencies doing similar or closely related work in freshwater habitats, but few operate in the ocean or have the word "marine" in their agency's name. It remained somewhat unclear to me how NMFS strategically prioritizes scientific work in these different habitats and how decisions are made about partnering with other agencies versus keeping all the work in house, especially in inland areas. The lack of information about salmon prey was mentioned in the context of the WCPFS ocean work, but prey/the food web was otherwise rarely

mentioned and disease was never mentioned at all, even though both are clearly important to the growth and survival of protected fish species.

Finally, as a Federal agency, NMFS has an important role in integrating data and information pertaining to protected fish species collected by State, tribal, local, academic, and private entities and placing it into the larger regional and national context. The increasingly complex and data-intensive life cycle modeling that plays a central role in the WCPFSP relies often to a very large degree on data collected by others. While side discussions with individual scientists gave me the impression that improving and maintaining the quality of data collected by others is a concern and efforts exist to assure method comparability, establish data quality criteria, and work with others to improve their data collection designs and methods, this was hardly mentioned throughout the three days of presentations and outside data sources were not always clearly indicated. It is important to acknowledge that the NMFS goal of "good science" cannot be accomplished by NMFS alone and also depends on "good science" conducted by others. NMFS needs to devise and/or continue to employ strategies to assure "good science" elsewhere, too.

III. Key Specific Findings and Recommendations

Theme 1: West Coast Protected Fish Species Program (Overview)

Observations: The program is carried out by two science centers with several divisions in each center, coordinated with the NMFS West Coast Region, and overseen by the NMFS Chief Scientist who initiated the current set of reviews in 2013. The degree to which WCPFSP activities carried out by the two centers are coordinated is unclear, although examples of scientists collaborating across centers and divisions were given in a number of later presentations. It was, however, not clear to me how much this coordination is due to the initiative of individual scientists versus a strategic effort by the two centers. Scientists also appear to communicate quite frequently with their regional management counterparts, although it is again not clear to me how much this is "built in." There is strong organizational separation between the science and management arms within NMFS. Prioritization of science activities happens at all levels of the organization and the two science centers have current strategic science plans. There are many important partners outside the agency who collaborate, cooperate, and/or use WCPFSP data and information. Funding and staffing are key issues. The initial presentations did not include some key information such as more complete staffing information and information about how scientific results are incorporated into NMFS decision making frameworks.

Strengths:

- Great scientists!
- Scientific leadership efforts including center-level strategic science plans and regional science reviews
- Open lines of communication to NMFS resource managers while maintaining adequate scientific independence through organizational separation and the chief scientist
- Science has contributed valuable information to recovery planning and biological opinions
- Cooperative and collaborative relationships with many partners

Challenges:

- Increasing costs, level or decreasing congressional budget allocations
- Maintaining a high-level, permanent scientific workforce over the long term
- Prioritizing scientific activities given increasing (and often urgent) science needs and limited funding
- Venturing into new scientific areas with limited funds
- Assuring relevance to NMFS resource managers, partners, and the public
- Comprehensive six-year program reviews present breadth versus depth challenge

Recommendations:

- Reevaluate the role of and use of reimbursable funds – instead of solely viewing it as a challenge, a substantial reimbursable program could also be viewed as an opportunity to strengthen the Centers' financial health and resilience as well as relationships with and relevance to outside entities; consider hiring permanent staff with reimbursable funds
- Coordination and integration among centers and divisions as well as with the Region could likely be improved
- One of the strengths of Federal science agencies is their national workforce and broad expertise. The WCPFSP could perhaps make greater efforts to pull in scientists from other regions and organizational entities within NOAA to help address short term and urgent science needs
- Clarify links to management and recovery outcomes
- Consider encouraging and rewarding development of projects with reimbursable funds provided by cooperative partners by ALL science center divisions (some already do it a lot, by necessity)
- Whenever possible, piggy-back work in new areas on existing, more established work
- Consider additional, less comprehensive, but more in-depth reviews (could look at USGS examples)

Theme 2: Salmon Recovery – Monitoring and Evaluation Data

Observations: There is a huge need for data about salmon and an even greater need for high quality data about salmon habitat. Exactly why this data is needed could have been more clearly articulated, but is of course quite obvious: the data is needed to understand and assess trends in the many life stages of the many salmon ESUs along the West Coast, to monitor and assess habitat requirement of and threats to these ESUs, and to feed comprehensive life cycle models aimed at evaluating and forecasting the effectiveness of salmon recovery and habitat restoration actions. Integration of monitoring, analysis/modeling, and management is key. Data availability is very uneven a in space and time, often with a bias to more easily accessible seasons or places. Not all restoration and conservation projects collect (good) enough data for management effectiveness evaluations. A lot of the data is collected by others outside of NMFS. It is unclear how data quality and method comparability is assured, especially for externally collected data.

Strengths:

- NMFS has an important role in tracking and integrating data and information pertaining to protected fish species collected by State, tribal, local, academic, and private entities,

putting it into the larger regional and national context, and making it publicly available in a geospatial framework
- There is a lot of relevant data, including data collected by others.
- NMFS is at the forefront of cutting edge sampling technology applications

Challenges:
- Uneven data availability and quality, very large spatial scales
- Assuring and controlling data quality including data collected by others – NMFS efforts in this regard were not presented
- Integration of monitoring with modeling and management
- Lack of relevant data, data gaps
- Collecting new types of data
- Dealing with "data deluge," including making data publicly accessible

Recommendations:
- Work with partners to improve and assure data quality and method comparability, fill data gaps, and make data available via, if possible, a common geospatial platform
- NMFS should promote common data standards and appropriate sampling designs, e.g. as part of five-year status reviews.
- Sampling designs should not be overly standardized because there is no "one-size-fits-all" design.
- Modelers and managers need to work closely with scientists generating the data they need for their models and management applications
- NMFS needs to maintain its leadership role in applying cutting-edge sampling techniques and designs

Theme 3: (Salmonid Freshwater and Estuarine) Habitat Science

Observations: Estuarine and freshwater habitat has been reduced and degraded by human activities, species invasions, and other changes; climate change will further alter salmon habitat. Habitat conservation and restoration is a vital component of species protection. WCPFSP scientists study salmon habitat in many ways and link changes in habitat attributes to salmon via a variety of modeling techniques. This includes adaptive management projects where science is directly linked to management actions such as the Elwha river dam removal project and many projects that explore more basic habitat associations and threats, including threats from novel contaminants of emerging concern. This work helps managers evaluate the effectiveness of habitat restoration alternatives and actions and prioritize new restoration actions. Challenges arise from high variability in fish responses to changes in habitat conditions, long response times, often simultaneous and frequently non-linear changes in several important habitat attributes, and the high cost of habitat restoration and the science needed to consistently track and fully understand its effects over the short and longer term, including the mechanisms and processes by which they occur. "Start to finish" adaptive management projects are rare, and many habitat restoration projects don't even include basic monitoring. The need for habitat work far exceeds available funds. Social scientists could help understand human perceptions of habitat protection and restoration and economists could help quantify economic costs and benefits.

Strengths:

- NMFS scientists have substantial expertise in many aspects of habitat science and have pioneered important new research areas. For example, NWFSC scientists are widely recognized as leaders in research on the effects of toxic chemical contaminants on salmonids and other species.
- NMFS has many talented modelers that can work with the habitat scientists to tease out salmonid responses to habitat changes.
- Habitat science is a particularly fruitful area for collaborative partnerships as evidenced by the long lists of collaborators presented in the habitat talks. Data collected by others is vital to the success of NMFS habitat studies.
- The WCPFSP habitat science portfolio includes many interesting case studies about the effects of habitat restoration and conservation, for example the Elwha dam removal project. These case studies provide vital lessons for future projects and can also serve important educational and outreach functions.
- The Elwha dam removal project includes clear questions and hypotheses (predictions) about expected changes, e.g. in sediments, that were then tested with a large amount of observations and analyses. Results contrary to expectations were often even more interesting than expected outcomes that actually occurred, although the very similar estimated and observed number of redds in the middle Elwha River in 2014 was remarkable.

Challenges:

- The need for habitat data is as infinite as the number of habitat changes and threats while funding is limited – how to prioritize and extrapolate to regions where no data is available?
- Assuring and controlling the quality of habitat data collected by others – NMFS efforts in this regard were not presented
- Habitat includes food resources and non-native species. Very little food web work was presented and there was only one presentation about non-native species. This may indicate a weakness in this area
- How to take a more ecosystem oriented approach to evaluating protected fish species habitat and its protection and restoration
- How to capitalize on the success of the Elwha river work and how to replicate it in other, more developed systems
- How to pursue habitat science, including contaminants work, in a more proactive way instead of the current opportunistic and reactive (to disasters) strategies
- How to incorporate studies of existing and future climate change effects
- How to assure close connections among modeling, monitoring, and management
- Cost of habitat protection and restoration and negative perceptions by the public

Recommendations:

- Prioritize habitat science work that clearly and convincingly articulates how it addresses the science needs of managers and others

- Prioritize habitat science work that includes a variety of collaborative partners that bring some funding to the project as well as additional expertise (e.g. in food webs, disease, and non-native species) and interest. This will lower costs and increase relevance and buy-in and lead to more comprehensive understanding
- Prioritize habitat science work that is or can be embedded in a clear and complete (all steps included, loop closed) adaptive management plan (preferably experimental, i.e. "active"). This will help assure good connections among modeling, monitoring/research, and habitat management and maximize learning
- Prioritize at least some habitat science work that lends itself to exploring new scientific questions and approaches
- More consistently adhere to the scientific method in all habitat work, including clear articulation of questions and hypotheses and appropriate ways to address them, including appropriate monitoring and study design and modeling to integrate and evaluate results
- Work with NMFS resource managers and other partners to develop a national strategy and secure Federal funding for contaminants work in support of fish protection and provide more support for proactive contaminants work. Also continue to acquire external funds for contaminants work. Perhaps also "piggy-back" more on other studies
- Work with partners to improve and assure habitat data quality and fill data gaps.
- Use the Elwha dam removal project more for educational and public outreach purposes, prioritize continued work on this project over the long term, include a strong communication program

Theme 4: Climate Change and Salmon Recovery

Observations: Climate change presents additional threats to salmonids and their habitat. Salmonid vulnerability to climate change and ways to build/increase resilience have to be considered in the context of the many other existing threats and habitat changes (e.g. flow alteration, predation and food web disruptions by non-natives, pollution, etc.). WCPFSP scientists use many approaches to study the effects of climate change and synthesize and communicate their results to managers and decisions makers. One presentation mentioned that climate change information can and is increasingly being provided for recovery planning, but it was not clear how and how much this information is actually being used by resource managers and incorporated into recovery plans.

Strengths:

- Active research on relevant topics, interesting case studies
- Integration with modeling
- Interesting work on evolution/adaption
- A lot of interest during the ongoing west coast drought
- Examples of decision support tools

Challenges:

- Modeling is key, but thorough, modern state-space life cycle models to address climate change effects have not yet been developed
- Oceans are likely crucial in fully assessing climate change effects on salmon, but ocean life stage model components appear underdeveloped and there is a lack of data

- Integrating climate change into (already complicated) recovery plans
- Incorporating climate change science into other salmon science areas, e.g. changes in predation and the food web

Recommendations:

- The ongoing drought along the west coast offers opportunities to obtain funding and collect data under extreme conditions that will likely become more common as climate change intensifies – use it
- Advance modeling with climate change in mind
- More critically assess climate change related data and information needs for freshwater and ocean habitats and life stages
- Require consideration and where possible integration of climate change in all salmon science areas
- Continue exploring how climate change can be considered in fish protection and recovery planning
- Further develop collaborations with NOAA's many excellent climate scientists. This may also lead to additional Federal funding

Theme 5: Survival in Rivers

Observations: Modern tagging technologies (esp. PIT and acoustic tags) have greatly improved our understanding of salmon survival in rivers. The WCPFSP has been at the forefront of development and application of these technologies and a lot of the salmon survival work is driven by clear and relevant questions. Results have directly contributed to changes in salmon management (e.g. less barging below Bonneville dam) and led to a much more complete and nuanced view of the role of predation in salmon survival. Predation hot spots have been detected with an innovative approach developed by the SWFSC that involves drifting tethered hatchery "bait." More adaptive management experiments should be conducted to evaluate the efficacy of predator removal in these hot spots and elsewhere. Other habitat alterations also play an important role in salmon survival, e.g. increasing temperature, low flows, and the absence of wetland habitat. Studies are underway to explore if and to what degree rice fields can provide surrogate wetland habitats and if passage through rice fields can improve salmon survival in the Sacramento valley.

Strengths:

- A large amount of tagging work has led to greatly improved understanding of salmon survival in the Columbia River and the California central valley
- Creative approaches to predation studies in the SWFSC (e.g. drifting tethered fish)
- Clear applications to management
- Integration with modeling

Challenges:

- The role of NMFS in tagging studies isn't entirely clear (to me). Many others are doing tagging studies. How does NMFS prioritize its own studies?

- Predation is important, but fish die because of other reasons, too, e.g. temperature – how to tease this apart
- Predation by protected marine mammals – what to do when one protected species eats another?

Recommendations:

- The SWFSC is very innovative in its salmon survival study approaches and should coordinate and/or collaborate with the NWFSC to test some of these approaches in the Northwest
- Conduct adaptive management experiments to evaluate the efficacy of predator removal in hot spots and elsewhere.
- Avoid focusing too narrowly on predation, conduct predation studies that also consider other stressors, e.g. increasing temperature, low flows, and the absence of wetland habitat
- Continue to investigate new ways to keep pinnipeds away from important salmon passage regions without violating Marine Mammal Protection Act and ESA requirements

Theme 6: Estuary and Ocean

Observations: There is much less scientific work conducted in the ocean than in inland regions which I found somewhat curious for a marine agency. Many other agencies are doing similar or closely related work in freshwater habitats, but few operate in the ocean. It remained somewhat unclear to me how NMFS strategically prioritizes scientific protected fish species work in the oceans versus in inland areas. Some of the coastal ocean work presented to the review panel also lacked clear questions, rigorous design, and connections to management applications. The long-term "Newport line" monitoring is valuable because of its long-term consistency and ability to reveal trends. Due to funding and other constraints, the other, shorter-term coastal monitoring seemed quite haphazard and results might be difficult to interpret. Some of the ocean work conducted by the two science centers seemed very well coordinated and delivered some interesting new results, e.g. about ocean life history strategies (e.g. coastal residents), stock-specific migratory patterns of juvenile salmon, and better Central Valley juvenile salmon growth and survival in the ocean than in the Sacramento River and San Francisco Estuary. Modeling work includes the development of a coupled ecosystem model for assessing ocean effects on central valley salmon growth off the coast of California by the SWFSC and "stop-light" indicators of ocean conditions by the NWFSC. These stoplight indicators have great potential for communicating conditions to a non-scientific audience, but the underlying models need to be further developed to test and assure indicator accuracy and enable forecasting. Estuarine work was presented as a series of interesting case studies with promising ideas for follow-up and additional studies. The lack of information about prey and considerable difficulties funding expensive ocean work were discussed as challenges.

Strengths:

- New insights into life history, growth, and stock-specific migratory patterns of of juvenile Chinook salmon in the coastal ocean
- Interesting estuarine case studies with meaningful results
- Substantial inter-center coordination and collaboration

- Efforts to communicate modeling results to a non-technical audience through "stop-light " indicators
- Modeling to integrate results

Challenges:

- Ocean studies are expensive and funding is hard to obtain
- The primary objective for developing the stop-light indicators was stated as "understanding processes," but it is not clear how much understanding is really gained because mechanisms are not really addressed. The secondary objective of forecasting does also not seem to be met yet
- There is not much data on salmon prey
- Lack of clear questions, rigorous design, and links to management, especially for some of the monitoring

Recommendations:

- Evaluate the need for and design of ocean monitoring
- Further develop the stop-light indicator modeling to improve accuracy and forecasting applications
- Consider possibilities for combining juvenile salmon ocean studies with other ocean studies and stock assessments to reduce costs and improve integration into and broader management and ecosystem context
- Continue the successful cooperation and collaboration of the two science centers

Theme 7: Harvest

Observations: There is an inherent tension between the economically and culturally important salmon harvest and protection of listed salmon stocks because listed stocks frequently intermingle with non-listed stocks. The WCPFSP has developed harvest assessment models and models to evaluate different harvest management strategies. Each science center has one full-time position to conduct management strategy evaluations. This is a critically important role in support of management decisions that are often highly scrutinized by State and tribal partners and a very interested public. Much of the data used for these evaluations comes from State and tribal partners. The rapport with State and tribal partners was characterized as "good." Project CROOS (Collaborative Research on Oregon Ocean Salmon) provides a very nice example of involving commercial ocean fishermen in research aimed at understanding migration patterns of individual salmon stocks via genetic stock identification (GSI) and establish relationships with oceanographic conditions. This seems to be a very promising approach to obtain interesting information that is relevant to management, but it will remain difficult to project were the fish that were already harvested might have come from and what migration patterns would be without harvest. The management goal is to avoid harvest of listed salmon stocks. Comparison of the GSI results with stock composition estimates obtained with the Fishery Regulation Assessment Model (FRAM) showed large differences, likely indicating a need to reassess the model, but it is unclear if and how the new data will really be used to inform harvest management. 3-D maps of fish locations are visually appealing and information-rich. The data may also be useful to assess migratory responses to the current persistent large warm patch of water in the Pacific Ocean

known as "the blob." Project CROOS appears to have collected a large amount of data that is now in need of in-depth analysis and application to management.
Strengths:

- The science centers have a critically important role in difficult harvest management strategy evaluations
- There appears to be good rapport with State and tribal partners
- Project CROOS is a great example of collaboration with fishermen
- Data from project CROOS may be useful for answering a variety of questions about adult migratory patterns and relationships with ocean conditions, including the current warm "blob"

Challenges:

- There are concerns about losing experienced harvest science staff through retirement; these scientists are hard to replace
- It is not yet clear how CROOS results can and will be used for harvest management
- It is not yet clear if the GSI method really works equally for all stocks; genetic analyses also remain quite expensive
- It was not mentioned how the quality of the data provided by tribes and States is assured

Recommendations:

- Evaluate when to use GSI and when to use coded wire tag approaches
- Conduct thorough and comprehensive data analysis of the CROOS data and evaluate applications to management
- Ensure quality of furnished data

Theme 8: Hatcheries

Observations: Hatchery science is a well-established component of the WCPFSP and has contributed greatly to improvements in hatchery management. The WCPFSP is well positioned to continue to provide leadership in hatchery science because of the broad range of relevant expertise among its scientists, including world class genetics expertise, along with established collaborations with many other entities. Hatchery science appeared to be particularly well integrated with management applications. Redfish Lake provides an interesting and apparently successful (but expensive) case study about reintroductions using hatchery stock. Ecological ramifications of hatchery releases remain difficult to assess and quantify; studies of ecological effects of large hatchery releases were not presented. Genetic tagging is a very promising new approach for monitoring hatchery salmon and assessing the efficacy of hatchery management and has already led to some management changes.
Strengths:

- Hatchery science is very well integrated with hatchery management
- Broad range of expertise to address hatchery issues
- Genetic tagging is a promising tool
- The Redfish Lake example showed that reintroductions can work when natural abundance is very low

Challenges:

- Ecological ramifications are difficult to assess and many questions remain
- The role of disease was not discussed
- It is not clear how much NMFS should become involved with reintroductions

Recommendations:

- Continue refining and testing genetic tools
- Evaluate prioritization of reintroduction studies

Theme 9: Evolution and Life History

Observations: The WCPFSP has a cadre of world-class geneticists who do cutting-edge work. Major accomplishments include establishment of ESUs and development of novel genetic tools and comparative studies about life history diversity and adaptations, most recently in the field of epigenetics and with regard to climate change. Genetic tools are combined with modeling to deliver interesting results, e.g. regarding the importance of resident steelhead and heritable life history changes in Snake River fall chinook salmon. The epigenetics work is in its infancy, but promises to be a very interesting and useful addition to the ongoing, more traditional genetics, especially with regard to hatchery management, but also with regard to habitat changes, including restoration efforts or toxic spills. Epigenetics may also help "scale up" some of the contaminants work done by the WCPFSP from the cellular and organismal level to fish populations.

Strengths:

- Generally cutting-edge science with a very strong team of scientists
- Major contributions to management, e.g. ESU establishment
- Combination of genetics and modeling tools
- Comparative study approaches, question and hypothesis-driven studies
- Linkages to management problems and applications
- Addition of epigenetics is promising

Challenges:

- SWFSC lacks rearing facilities similar to the Manchester Research Station which limits the types of experiments that can be done by the SWFSC
- The field of epigenetics is very new and mechanisms for passing on epigenetic information remains unclear; these mechanisms may be better investigated with more traditional model organisms than with protected fish species
- Funding for epigenetics studies is tenuous
- Modeling has so far been used mainly to describe geographic variations, not yet as a predictive tool; unclear why specific modeling approach was selected

Recommendations:

- Develop a strategy for epigenetics science (prioritization, funding, etc.) in the WCPFSP and throughout NMFS
- Work with other WCPFSP modelers to evaluate use of models

Theme 10: Life Cycle Modeling and Synthesis

Observations: Conceptual and quantitative models are essential for analysis and synthesis of scientific data and integration with management applications. The fish species investigated by the WCPFSP have complicated life cycles and life cycle models (LCMs) are great tools for integrating much of the data and information produced by the WCPFS. Life cycle modeling in the WCPFSP has clearly made great progress in recent years. The importance of life cycle modeling is now widely recognized and LCMs are increasingly required in Biological Opinions and even court orders. In the Columbia Basin, modeling is conducted by collaborative working groups as part of the Columbia Basin Adaptive Management Implementation Plan (AMIP). SWFSC LCMs are intended to provide decision support for water project operations in California's central valley and include several complementary modeling approaches. Overall, LCMs are becoming increasingly complex and data intensive which presents many challenges. Both centers lack enough permanent staff with the high level quantitative skills needed to deal with these challenges. Instead, the centers rely heavily on contract employees and collaborators.

Strengths:

- Powerful integrative and predictive tools that link study results and management applications
- Ongoing, active work in both centers
- Clear connections to management applications (e.g. Biological Opinions, habitat restoration)
- Collaborative AMIP working groups
- Participation of WCPFSP modelers in collaborative modeling workshops and other scientific events

Challenges:

- Lack of relevant data resulting in having to substitute data from elsewhere
- Variability in data quality make it difficult to appropriately incorporate data into models, observation error needs to be carefully considered
- Many biologically/ecologically processes and responses are difficult to incorporate into LCMs, e.g. sub-lethal effects, evolution in response to climate change, response to slow changes, e.g. reestablishment of riparian habitat over many years, etc.
- Strong reliance on non-permanent/contract employees
- Complex LFMs may be hard to use by managers and results may be difficult to interpret
- There is a proliferation of seemingly uncoordinated modeling efforts and models within NMFS and elsewhere

Recommendations:

- Develop a LCM strategy for the WCPFSP that includes common modeling standards/best practices, more coordination among the two centers and with partners, strategies to invest in more permanent quantitative staff, and approaches to communicate model outputs and make them more user friendly
- Consider pulling in quantitative NOAA scientists from elsewhere in NOAA
- Clearly articulate the conceptual models underlying the LCMs and state assumptions
- Work with partners to assure data quality

- Work closely with scientists collecting data to ensure appropriate sampling design and that monitoring and experimental work needed to fill model data and information gaps is prioritized

Theme 11: Green Sturgeon, Rockfish, and Eulachon

Observations: Compared to salmon, there is much less scientific activity and thus much more limited data and information about green sturgeon, eulachon, and Puget Sound rockfish species. However, there has apparently been a large the amount of scientific progress in a relatively short amount of time with regard to these species - it seemed that relatively little funding really went a long way. Securing more funding is clearly essential for answering more difficult questions about how to protect these species. This is particularly important for green sturgeon because its abundance is very low. One way to accomplish this might be to more systematically leverage existing studies on other species to also answer questions pertinent to these species. This might also help better understand fish communities. By design, the WCPFSP is focused on individual species to fulfil mandates and requirements under the ESA, but species cannot be understood or managed on their own; the community and ecosystem context is important. Another way to secure more funding and/or reduce internal NMFS costs for work on additional species and communities is a more strategic pursuit of external funding and collaborations with State, tribal, academic, local and private entities, including "citizen scientists."

Strengths:

- A lot has been learned in recent years
- DIDSON cameras have been successfully deployed to map and count the adult green sturgeon
- Adult green sturgeon tolerate tagging well and tagging studies have produced very interesting information about their movements and use of different habitats

Challenges:

- Easy questions have been answered, questions will be more difficult to answer in the future
- Funding is very limited
- Green sturgeon abundance is very low
- Juveniles green sturgeon are hard to catch and tag and it is difficult to quantify recruitment and growth; so far only abundance is available to set recovery goals
- The reasons for the eulachon decline after the mid-1990s remain unknown

Recommendations:

- Leverage existing studies on other species
- Develop strategies to acquire more funding to work on these species, esp. green sturgeon

Theme 12: Non-native species research

Non-native species are an increasingly dominant component of west coast ecosystems and interact with protected fish species in many ways; threats posed by non-native species include food web disruptions and lowered food quality, changes to physical habitat, and increased predation levels. Investigations of non-native species and their effects on protected fish species

do not appear to play a very prominent role in the WCPFSP and linkages to management appear somewhat weak.

Strengths:

- Some interesting examples of non-native species research have been conducted by the WCPFSP
- There are opportunities for partnering with others, including recreational fishing groups etc.

Challenges:

- Non-native species are everywhere and more will come – how to prioritize work?
- How to connect non-native species research and information to management actions
- Funding is limited

Recommendations:

- Develop a strategy for prioritizing non-native species research relevant to protected fish species management
- Partner with others, including non-scientists
- Conduct non-native species research in the context of habitat management and studies and wherever possible in an adaptive management framework

(IV. Conclusions: see II.)